China Council for International Cooperation on Environment and Development (CCICED)

# High-Quality Development of River Basins and Adaptation to Climate Change:

# Regional Collaborative Governance Mechanisms

**CCICED Special Policy Study Report**

**CCICED**

**August, 2023**

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# Executive Summary


China has entered a new phase of watershed governance. Climate change has clear impacts on natural resources and land use and increases the uncertainty and risk of extreme weather events. Therefore, China's new strategic goals for active climate change adaptation, "dual carbon" targets, resilience, and shared prosperity will require new policies to be successfully achieved. This study builds on previous research findings, such as the 2004 and 2022 Special Policy Study (SPS) on river basin comprehensive management and the 2018 and 2019 studies on ecological compensation mechanisms, as well as inspired by the ocean governance SPS, to propose policy recommendations for new challenges that aim to strengthen resilience and embed green transition.

**1. Case studies on improving resilience in the governance of large river basins in China and internationally**

This report explores systematic and forward-looking approaches to sustainable development governance in response to climate change in China’s Yangtze River and other river basins through a comparative study of the collaborative governance experiences of other large river basins around the world. While addressing the key issues of current watershed development in China, this study can also make an important contribution to the development and governance of other watersheds.

In response to the outstanding ecological and environmental problems in China’s river basins, the Chinese government has changed the concept of river basin management, which was originally focused on economic development, to “ecological priority and green development” and has issued a series of laws, regulations, policy documents, and special plans. The Chinese government has established the “Leading Group for Promoting the Development of Yangtze River Economic Belt” as the top-level body to guide the governance of the river basin, to strengthen the coordination of government departments in different fields and at different levels for the governance of the river basin, and to promote the comprehensive governance of the river basin and deepen regional coordination.

This report conducts empirical case studies on different sub-basins of the upper, middle, and lower reaches of the Yangtze, Rhine, and Mississippi from the Northern Hemisphere and the Amazon and Zambezi rivers from the Southern Hemisphere, and analyzes the specific characteristics of the new challenges of the current phase in different parts of the basin in the context of climate change impacts, the stage of economic and social development—including gender inequalities and their impact—and the variability of development claims in the basin, in order to provide more empirical lessons for improving the basin governance system.

Lessons from the original watershed interventions suggest that, according to current scientific theories, a different approach may be applied to many past watershed problems. This study argues that when developing watershed interventions, the relevant governance actors must assess both the short-term and the long-term effects of the river’s hydrodynamics, water morphology, and water ecology. The corresponding assessment should be carried out in the appropriate spatial scale

of the watershed. River systems are highly dynamic, and interventions in one part of the system can have short- or long-term impacts on other parts of the system through altering streamflow, sediment dynamics, and ecological processes.

Lessons from history have shown that damage from extreme climate-related weather events can be prevented in this new era of climate change by a shift in governance from reactive responses to damages to early proactive actions on watershed resilience and climate adaptation. The time horizon for forecasting should look ahead to 2100. Coordinated governance of watersheds requires the commitment of all parties involved; otherwise, it is difficult to develop effective outcomes. The European experience shows that a clear commitment to basin-wide governance objectives can reduce the complexity of basin coordination at smaller spatial scales while ensuring consistency in the implementation of basin governance policies.

According to scientific research, the climate crisis is upon us, and the urgency of the risk and the need for climate adaptation can no longer be ignored. China and other countries need to respond proactively and comprehensively to advance the state of adaptation in river basins to climate change while furthering efforts on climate mitigation. Action includes and requires defining and advancing broader and deeper methods to boost human resilience and physical assets like infrastructure, and economic as well as environmental resilience. The realization of the need for integrated approaches to basin management is growing—and that includes the need to work across sectors and ministries and other agencies. China’s State Council should direct the development of mechanisms for regional cooperation that bring together all actors to ensure the climate challenge is fully addressed in basins and to support long-term sustainable, inclusive, and healthy development. Especially with the publishing of the Laws on Yangtze River Protection and Yellow River Protection, the stage is set for integrated and comprehensive management of river basins in the face of climate change.

## 2. Main policy recommendations

The Yangtze River Protection Law, officially implemented on March 1, 2021, takes "ecological priority and green development" as the legislative concept and establishes the "National Yangtze River Basin Coordination Mechanism" and the "Yangtze River Basin Local Collaboration Mechanism." This has promoted a major change in China's river basin management system from "compartmentalization" to "integration." At the symposium on the comprehensive promotion of Yangtze River Economic Belt development in 2020, General Secretary Xi Jinping stated to "make the Yangtze River Economic Belt the main battlefield of China's ecological priority and green development, the main artery of smooth domestic and international double circulation, and the main force of leading high-quality economic development."

Studies such as those of the IPCC show that the risk of extreme climate events—including floods and droughts—is increasing, that increased resilience is critical to economic and energy security and shared human prosperity, and that immediate action should be taken to adapt to the impacts of climate change. In the new context of global responses to climate change and China's promotion of common prosperity, and in order to better implement the General Secretary's statement, we propose the following collaborative governance recommendations:

**First**, it should be fully recognized that enhancing river basin resilience and climate resilience has a high and comprehensive value of safety and security, economic investment, low-carbon development, and ecological protection. We recommend that enhancing river basin resilience and climate resilience, focused on green transformation, should be taken into consideration in the overall economic and social development of the watershed. In addition to "defensive" measures to cope with the urgent pressure of climate risks, the required governance strategy should also adopt "innovative" measures in terms of technology and governance models.

**Second,** Cross-sectoral, cross-administrative, and multidisciplinary collaboration mechanisms should be established that involve government and enterprises, as well as the public and NGOs. Drawing on lessons learned from the EU Water Framework Directive, we recommend improving the legal and regulatory system under the framework of the Yangtze River and other Basin Protection Laws, by establishing comprehensive law enforcement mechanisms in which specific targets should be clarified, such as for chemical pollution and water quality, in various regions and time phases, corresponding to legal requirements and the master plan of the basin. This should ensure the in-depth implementation of laws related to basin management. Based on the common vision of the region, regional coordination across space, time and sectors should be strengthened to promote the sustainable development and resilience of the river basin in the context of climate change. This includes:

- Strengthening spatial synergy, based on spatial units of sub-basins and sub-regions, and forming special coordination mechanisms based on specific synergistic factors and issues to avoid transferring problems to other areas.

- Strengthening sectoral collaboration, by developing a common watershed development strategy by relevant sectors such as industry, agriculture, ecology, energy, and transportation, to improve cross-sectoral effectiveness and avoid transferring negative impacts to other sectors.

- Enhancing temporal synergy by developing watershed governance policies and measures based on lessons learned from history (evolutionary best practices), and also by looking ahead to the likely impacts of future climate change. Foresight studies should have a time horizon of at least 100 years to prevent problems from being transferred to the future.

**Third,** we propose to establish a sustainable hydropower fund as a mechanism for eco-compensation exchanges between downstream water consumers and upstream actors in the river basin. Such a water fund can be used to implement the "dual carbon" strategy, including developing modern agriculture (renewable agriculture), transforming the energy mix, and adopting nature-based solutions to promote high-quality and green development in the basin.

**Fourth,** China needs to accelerate the formulation of the Yangtze River Basin Development Plan and the Territorial Spatial Plan and to make sure that solutions to cope with climate change and promote the implementation of the "double carbon" strategy are comprehensive, covering the entire river basin, multiple sectors, and multiple objectives. We should focus on typical areas with dense populations and ecological sensitivity, such as secondary tributaries, large lake basins, and estuaries, to promote the green and sustainable development of large river basins with regional synergy and provide a model for the management of rivers in China and the world. For instance, the Jialing River and other secondary tributaries should actively explore "integrated resilience solutions" to provide a demonstration of green and low-carbon models for the modern development of less-developed inland areas. Taihu Lake and other large lake basins should explore the transformation of the regional spatial development model, establish a synergistic mechanism for “nature-based solutions.” The Pearl River Estuary and other large river estuaries should strengthen the coastal zone governance of the land and sea as an important issue of regional collaboration and form a "comprehensive solution of cross-regional and cross-system cooperation."

**Fifth,** we recommend to establish a comprehensive assessment mechanism for watersheds to systematically evaluate the long-term stresses and short-term impacts of climate change at the basin-wide level, analyze the adaptability of current policies, measures, and construction behaviours in different regions, cities, and sectors, and make fully integrated actions a prerequisite for formulating resilience policies and implementing major construction work in synergy with upstream and downstream basins.

**Sixth,** given the gender-differentiated impacts of climate change on women and men from diverse backgrounds, special attention should be given to gender and social equity issues, and to increasing the benefits and participation of women and other marginalized groups in watershed governance through a variety of means. This will ensure that their unique perspectives, needs, and capacities are incorporated, contributing to sustainable development outcomes.

**Keywords：River basins, integrated approaches, environment, resilience, nature, regional collaboration, climate**

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# High-Quality Development of River Basins and Adaptation to Climate Change: Regional Collaborative Governance Mechanisms

## 1. Research Background: Setting & Background

A watershed is a complex system characterized by changes at different temporal and spatial scales. There are uncertainties associated with predicting and managing these changes. Some countries and regions have developed relatively mature governance practices and experience in many aspects of watershed management, including the identification of watershed problems and pressures, the promotion of a conceptual consensus to undertake holistic planning of watersheds, and some specific working methods, such as nature-based solutions, encouraging diverse stakeholder participation, including that of women and other marginalized groups, and integrating long-term needs and short-term actions. At the same time, however, there is still a long way to go to integrate watershed management as a system. Building on previous NCC studies on integrated watershed management (2004) and ecological compensation (2018 and 2019), as well as several CCICED studies of the Yangtze River, the 2023 joint report of China and The Netherlands, a CCICED event at the 2023 UN Water Summit, and other developments, this report focuses on identifying effective regional cooperation mechanisms in the increasingly urgent context of climate change impacts across the Yangtze River basin, from extreme flooding to drought. The report promotes the use of relevant research recommendations in China as well as globally.

### 1.1 Five-year research plan on watersheds

This year's study is part of the CCICED's 5-year research plan series on watersheds (see table below). The research plan of the series proposes a series of objectives for the next five years of research, including: (i) identifying the general risks, challenges and specific manifestations of major watersheds; (ii) establishing a watershed-specific stress-risk and adaptation evaluation framework to achieve an improved level of integrated watershed management; (iii) summarizing the development trends and successful experiences of the world's major watersheds in related aspects; (iv) combining the experiences of China, Europe, the United States and other countries and regions in major river basins and estuaries; (v) summarize the development trends and successful experiences of major watersheds in the world in related areas; (vi) propose comprehensive cross-regional collaborative governance recommendations, taking into account the experiences of China, Europe, the United States, and other countries and regions in major watershed governance.

Table 1. Principles and research priorities for the five-year work on SPS in the CCICED watershed governance

| Study Year | Annual research principles/themes | Possible research focus |
|---|---|---|
| 2022-2023 | Fulfilling responsibility from source to coast | Regional cooperation mechanisms |
| 2023-2024 | Planning steps according to the 100-year vision | Proactive adaptation and resilience to projected climate change |
| 2024-2025 | Everyone participates and develops a common vision | Collaborative organization based on multidisciplinary interests |
| 2025-2026 | Adaptation to climate change and other major river stressors in all aspects of riverine regional management | Coping with uncertainty about climate change, other stressors and disasters |
| 2026-2027 | Continuous strengthening and innovation | Management methods, knowledge plans, policy tools and forward-looking financing mechanisms, etc.; international exchange |

### 1.2 Annual research objectives

This year's study explores governance approaches to climate change in China's Yangtze River and other river basins, globally, through a comparative study of basin governance experiences around the world. This research is conducted within the context of sustainable development and the need for integrated and systems-based whole-of-basin governance models to address the growing risks of climate change. This report provides targeted recommendations for high-quality development and climate adaptation in Chinese and global watersheds. The specific research objectives are:

- Targeted learning from international and Chinese experience in watershed governance.
- Studying regional coordination of river basins at both macro and meso levels. The macro level focuses on the history of regional governance in international and Chinese large river basins. The meso level focuses on case studies of sub-basin units, where targeted regional cooperation mechanisms are discussed around specific issues in the case basins.
- Focusing on typical case studies in three types of areas: upstream sub-basins, estuarine areas, and downstream great lakes regions, and examining the problems and solutions facing the coordinated regional management of China's large river basins through comparisons with the Rhine and Mississippi river basins and other basins of global concern.
- Adopting a problem-oriented research approach to compare and draw on international experience for proposing policy recommendations to strengthen regional cooperation in China and global watersheds.

### 1.3 Definition of regional coordination of watershed governance

One of the key topics of this report is governance at the regional scale. The report refers to this as "regional governance," "regional coordination," or "regional coordinated governance mechanisms." In the cases discussed in the report, the meaning of the term "region" varies in terms of the spatial units involved. In China, the term "region" refers to coordination among provinces; in the case of the Mississippi River Basin, coordination refers to coordination among states in collaboration with the federal government; and in the case of the Rhine River, it refers to coordination among different sub-state Dutch regions and among the countries (states) along the Rhine. The latter is highly relevant because the management of the Rhine basin is closely related to the EU Water Framework Directive. In addition, the "regional coordination" proposed in this report also involves coordination between different government departments within the same basin spatial unit, as well as coordination between government and various actors, such as enterprises, the public, and NGOs. In order to promote the success of regional coordination, it is necessary to effectively coordinate the individual interests of various stakeholders with the public interests (e.g., agriculture, natural environment protection, water quality, navigation, flood control), including cross-sectoral coordination among different government agencies, as well as coordination between government and enterprises, NGOs, and other public representatives.

## 2. Governance history, issues, and challenges

### 2.1 The evolution of the Yangtze River Basin Governance

Based on the results of the analysis of the change in the proportion of topics in Chinese government policy documents on the Yangtze River (based on the semantic analysis method) and the case study of the impact of major events on river basin governance, the study finds gradual and intermittent change in the governance policy of the Yangtze River basin. Based on the identification of key time points, the governance history of the Yangtze River basin since 1949 can be divided into four phases.

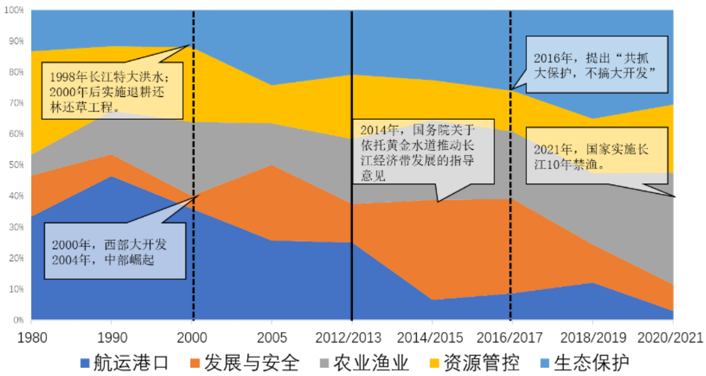


Figure 1: Share of policy documents by topic in the Yangtze River Basin, 1980–2021

### 2.2 The initial stage (1949 to 1978)

In the context of the planned economy at that time, various management activities in the Yangtze River basin were mainly arranged and deployed at the national level, with the focus on two key areas of management: flood control and water conservation, and power generation. Under the unified arrangement of the state, a number of embankments, water conservancy, and hydropower hubs and other projects were built in the Yangtze River basin during this period.

*Economic development-led phase (1978-1998)*

After 1978, with the implementation of China's reform and opening-up policy, the Yangtze River basin governance entered a stage with economic development as the core. In addition to flood control and power generation, water resources development and deployment, integrated development of shipping and industrial development along the Yangtze River basin also became the focus of river basin management. The structure of governmental bodies involved in river basin governance has become more diversified. In addition to the water conservancy department, the importance of development and reform, ecological and environmental protection, urban and rural construction, land and resources, and transportation departments at the national level has increased in the governance of the Yangtze River basin, but the coordination of different basin governance bodies is insufficient.

*Initial transformation phase (1998-2012)*

After the 1998 Yangtze River floods, the Chinese government and public opinion paid more attention to the risk of flooding in the Yangtze River, and the policy of watershed management changed to integrate development and protection and strengthen systemic management, but the change in the concept of watershed management was not complete due to the limitations of the development stage. After the 1998 floods, the Chinese government began to carry out ecological management projects, such as returning farmland to forests and lakes in the upper and middle reaches on a large scale. After the 1998 floods, the Chinese government began to carry out ecological management projects in the upper and middle reaches, such as returning farmland to forests and lakes. However, at that stage, the center of watershed management was still economic development, with many industrial enterprises clustered along the river and the excessive use of pesticides and chemical fertilizers and other irrational watershed development measures, which led to more serious ecological and environmental problems facing the Yangtze River basin. In addition to the central government, local governments at the provincial, municipal, and county levels within the river basin have significantly increased their role in the governance of the river basin from the goal of developing the local economy, and have carried out a large number of economic development-type governance activities, such as urban construction, industrial development zone construction, port development, and mining exploitation, but the regional coordination mechanism across administrative regions at the local level is not perfect.

*High-quality development and protection phase (2012 to present)*

Since the Chinese government incorporated the construction of ecological civilization into the overall national strategy in 2012, the governance policy of the Yangtze River basin has gradually changed; especially after the release of the Outline of the Yangtze River Economic Belt Development Plan in 2016, the governance orientation of the basin has clearly changed from “prioritizing economic development” to “prioritizing ecology and green development.” The Yangtze River Protection Law of the People's Republic of China came into force in March 2021. With the Yangtze River Protection Law and the Yangtze River Economic Belt Development Plan as the guiding principles, the Chinese government has issued a series of laws, regulations, policy documents and special plans on the Yangtze River Basin, and the legal and policy system of regional coordination and governance has been improved. In addition, after 2016, the Chinese government established the "Leading Group for Promoting the Development of Yangtze River Economic Belt" as the top-level body of the central government to guide the governance of the Yangtze River basin, strengthen the coordination of different areas and levels of government departments in the governance of the basin, and promote the deepening of comprehensive governance and regional coordination of the basin. Local governments in sub-regions, such as the Yangtze River Delta, Chengdu and Chongqing, and the middle reaches of the Yangtze River, have also strengthened cross-regional basin coordination.

Although coordinated regional governance has been strengthened since 2012, collaborative governance in the Yangtze River basin is still in its infancy in terms of biodiversity conservation, coordination between hydropower development and environmental protection in upstream areas, and efficient development of shorelines in the middle and lower reaches. Flooding and drought events, like the ones that have occurred in recent years, may significantly impact hydropower output and lead to an increase of investments in coal-fired power stations to counter the decline of hydropower output, when renewable energy capacity by wind and solar is not yet sufficient to cover this decline.

### 2.3 The evolution of the governance of the Rhine River basin

The history of Rhine basin governance shows that systematic shifts in basin interventions, and the accompanying emergence of new governance structures, are often triggered by natural disasters, i.e., devastating events with significant social impacts. In most cases, however, interventions were proposed before the corresponding major destructive events occurred. Natural disaster events only drive the consensus on the urgency of implementing these measures and programs at the social and political levels. The following major events are particularly relevant regarding the evolution of Rhine basin governance.

*French invasion of Holland (1672)*

In 1672, the Dutch dug an artificial channel in the lower Rhine to defend against the French invasion. This channel later formed a new tributary of the Rhine and now marks the division of the Rhine into the Waal River and the Pannerden Canal. The new tributaries were unstable in the beginning, however, and continued to silt up for the next century. To solve these problems, the first central government agency was established in The Netherlands (the Water Authority in 1798), which later evolved into the Dutch National Water Authority.

*Mannheim Act (1868)*

In 1868, the countries of the Rhine basin signed the Mannheim Convention, which guaranteed a regime of freedom of navigation on the Rhine. Since then, it has been an important treaty for facilitating trade relations between European countries.

*Zuiderzee ('Southern Sea') Flood (1916)*

In 1916, a major coastal flood occurred of the Zuiderzee ("Southern Sea"), an inland sea that was connected to the North Sea and reached from the north to the middle of The Netherlands. Parts of Amsterdam and some towns along the banks of this former sea were flooded. This flood prompted the construction of the Afsluitdijk dam in 1932. This dam transformed the Southern Sea into the largest lake in The Netherlands (Lake IJssel).

*Establishment of the International Commission for the Protection of the Rhine (ICPR, 1950)*

In 1950, the International Commission for the Protection of the Rhine (ICPR) was established jointly by The Netherlands, Switzerland, France, Germany, and Luxembourg in Basel, Switzerland, seeking to address the increasing river pollution of the Rhine through cooperation. In 1970, as the basin countries became increasingly aware that sustainable basin management could only be achieved through increased cross-border cooperation, the International Commission on Hydrology of the Rhine (CHR) was established.

*North Sea Flood (1953)*

After the North Sea flood of 1953, the Dutch government initiated the construction of the Delta Project. The construction of the project was directed by the Special Committee on the Delta. Although the Dutch government made a clear decision to build the Delta Project, the project was also hindered by social opposition in its implementation.

*Sandoz chemical leak disaster (1986)*

In 1986, a fire at the Sandoz Chemical Company in Basel, Switzerland, spilled a large quantity of pesticides into the Rhine River, causing an environmental disaster throughout the river's lower reaches. In response to this disaster, the Rhine riparian countries initiated ecological restoration of the Rhine, including the implementation of the ICPR Rhine Action Plan (1987).

*Extremely large river discharges (1993, 1995)*

The Rhine experienced extreme river discharges in 1993 and 1995, which put the dikes along the river to the test. In response, the Dutch government launched the "Room for the River" project: a series of measures along the Rhine to increase the river's water discharge capacity. A planning tool was developed to visualize the effect of all sorts of interventions and to facilitate the participation of different stakeholders and government levels in the decision-making process.

*Development of the EU Water Framework Directive (2000) and the Floods Directive (2007)*

The development of the EU Water Framework Directive in 2000 meant that member states had to work together to develop river basin management plans. In the context of water resources management, the Directive focuses on controlling the water ecological quality of the basin. Similarly, for flood risk management, flood risk management plans for each basin must be developed within the framework of the European Floods Directive.

### 2.4 The evolution of the Mississippi River Basin governance

The Mississippi River basin covers 41% of the contiguous United States. The Mississippi River and its tributaries have approximately 10,000 miles of government-maintained navigable waterways. Navigation in the Upper Mississippi, Ohio and Red River basins is secured through a series of locks and dams. Navigation on the Missouri, Middle Mississippi and Lower Mississippi rivers is maintained through levee construction, bank improvement, and channel dredging.

The history of Mississippi River governance illustrates the complexity of the division of responsibilities in watershed management between the U.S. federal government and state governments. The complexity of watershed governance has been exacerbated and regional governance has become less efficient by the large number of governance responsibilities vested in the states and the lack of cooperation among the states.

*Division of responsibilities between the federal government and the state governments since the early 19th century*

Development of the Mississippi River basin began in the early 1800s, after which the U.S. federal government assumed responsibility for maintaining navigation on America's major rivers. As the settled population in the basin grew, local governments assumed responsibility for providing flood protection for the basin's flood-risk residents. Under the U.S. Constitution, all powers not expressly granted to the federal government in the Constitution were left to the states. Therefore, the power to manage water resources (excluding navigation) belongs to the state governments.

*Mississippi River Commission (1879)*

In 1879, the U.S. Congress approved the creation of the Mississippi River Commission to oversee activities involving the Mississippi River and assigned the Commission specific responsibilities for maintaining river navigation in the basin.

*Great Floods (1927, 1936)*

In 1927, a catastrophic flood swept through the Lower Mississippi River basin, disrupting navigation and causing millions of dollars in damage. In 1928, the federal government assigned the Mississippi River Commission the responsibility of managing navigation on the Lower Mississippi River and working with the states to adopt a systematic approach to flood control. In 1936, after another major flood, the U.S. federal government began to strengthen flood control programs. The federal government would assume responsibility for the construction of major flood control projects when the benefits of these projects exceeded their costs, and proposed that the implementation of major flood control projects be carried out on a case-by-case basis in each locality. But the United States still has not assigned responsibility for overall watershed-level oversight to any federal agency. Meanwhile, at the request of the Missouri River Basin states, the U.S. federal government has assumed responsibility for the construction of six major dams on the mainstem of the Missouri River for flood control, irrigation, and maintenance of the Missouri River navigation system, but not for watershed oversight.

*Establishment (1965) and abolition (1981) of the Basin Commission*

In 1965, recognizing the real challenges to the operation of water systems by state and local agencies, the U.S. Congress enacted a water resources planning law requiring the establishment of basin commissions and water resources councils in major basins to coordinate federal and state activities in the area of water resources. In 1981, largely because the states complained that the basin commissions were interfering with their constitutional authority, the President of the United States ordered The River Basin Commission abolished and support for the Water Resources Board was withdrawn. At the same time, growing competition for water resources in the Missouri River Basin led the states in the basin to question the federal government's management of the river, even though the states could not agree among themselves on how the system would work. This led to lawsuits against the federal government and the states and triggered judicial decisions. These rulings essentially told the states that the federal government would operate navigation and flood control dams on the Missouri River until the states worked out a cooperative solution. In the Missouri River Basin, the U.S. federal government's role is to manage the dams, not to systematically manage water conservation and development activities in the basin as the Mississippi River Commission has done in the Lower Mississippi River basin.

*Current challenges*

Today, the Mississippi Basin faces significant challenges in achieving cooperation and collaboration among the relevant governance actors in water resources development, flood control, navigation and ecological protection. At the top of the list is the federal system in place in the United States, which has transferred responsibility for management of most water resource activities to the state governments. The states also face challenges in internal cooperation, depending on the nature of their constitutions and the provisions in those constitutions regarding the powers of lower levels of self-governance within the states. In some states, there is a high degree of cooperation and collaboration between levels of government and with NGOs; in others, the situation leaves much to be desired. The second challenge is the upstream and downstream coordination issues faced worldwide. On tributaries located entirely within a state, that state can manage most of the watershed activities. In other cases, too little or too much water in a river can quickly lead to disagreement or even conflict if states share a river segment.

**Box 1: The Transformation of Amazon River Governance**

The Amazon River drainage basin covers an area of about 6.9 million square kilometres, located in Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela. The Amazon is the world's largest river in terms of runoff, with an average flow of 150,000 cubic metres per second and 18% of the world's freshwater resources. The forest ecosystem in the basin itself helps regulate climate and rainfall patterns on a local and regional scale, providing favourable conditions for agricultural production and food security throughout the South American continent and beyond. The Amazon is also an important buffer against climate change. Of the 2.4 billion tons of carbon absorbed by the global atmosphere each year, 20%–25% is absorbed by the forests of the Amazon basin. The entire Amazon basin stores nearly 100 billion tons of carbon, which is roughly equivalent to a decade of global carbon emissions.

The significant increase in Amazon forest fires and deforestation areas in 2019 confirms the serious damage and risks caused by human activities in the basin, including deforestation and the spreading encroachment of pastures and agricultural lands into ecological reserves. As part of a sustainable development plan for the Amazon, a systematic long-term prevention strategy is needed.

The current climate crisis provides a major opportunity to move the Amazon River Basin toward sustainable development in order to prevent human development activities in the basin from breaching what scientists call the ecosystem stability tipping point, where the basin and its ecosystems will not be able to maintain a stable state by self-regulation. With the support of the Amazon Cooperation Treaty Organization (ACTO), the United Nations Environment Program (UNEP), the Organization of American States (OAS) and the Global Environment Facility (GEF) program, eight countries within the Amazon River Basin have been working on the integrated and sustainable management of transboundary water resources since the ACTO treaty was signed in 1978. Ongoing work continues to focus on strengthening the institutional framework for planning and implementing strategic activities to promote the conservation and sustainable management of the basin's water resources, as well as to address climate change. The Strategic Action Program (SAP) implementation described below includes the execution of a portfolio of on-the-ground projects ranging from water resources management, agricultural improvements, and biodiversity conservation that are coordinated through ACTO’s secretariat and include consensus building among the eight countries in the basin.

The project developed a SAP for the basin, approved in 2018 and launched for implementation by the Amazon Cooperation Treaty Organization in February 2020. The SAP is mainly based on the following consensus: i) a shared vision for integrated water resources management and sustainable development in the Amazon basin; ii) the conduct of a regional transboundary diagnostic analysis (TDA) to synthesize and identify transboundary issues in the basin through broad consultations; and iii) the results and recommendations of activities, regional initiatives promoted by the Amazon Cooperation Treaty Organization (ACOT).

**Box 2: Transformation of Zambezi River Basin Governance**

The Zambezi River Basin covers an area of 1.6 million square kilometres and has a total population of approximately 47 million people within the basin; the river catchment area is located in eight countries: Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe. The main strategic issue facing the basin is balancing economic growth and environmental sustainability while coping with the risk of droughts and floods due to a highly variable climate, which is being further exacerbated by climate change. Poverty and poverty-induced watershed degradation are the greatest threats to people, ecosystems, and future development in the Zambezi River Basin. Unless concerted efforts are made to improve the livelihoods of the poorest people, this degradation is likely to increase. The poorest people make up more than two-thirds of the basin's population, and most of them are engaged in smallholder rain-fed agriculture, which accounts for 96% of agricultural activity. Given the current relative underutilization of water resources in the basin, the plan increases water use to 31% of the historical average runoff, which is generally considered to be still below the water scarcity threshold. However, under possible future climatic drought scenarios, some areas of the basin may experience water shortages.

Climate change has important implications for development in the Zambezi River Basin and raises the importance of strengthening regional governance. Under the driest climate change scenario, losses could exceed $2.3 billion per year, while under the wettest scenario, gains could increase by $400 million per year. These impacts are primarily related to hydropower generation, agriculture, and freshwater supply.

The Zambia River Commission developed a strategic plan for the basin in 2018. In this plan, the preferred future development path is mapped out with the aim of maximizing the economic benefits of water resources development in the basin while ensuring that moderate ecological flows are maintained, and flood protection is provided. Cooperation and coordination of cross-basin governance activities led by the Zambezi River Commission have the potential to reduce the impact of climate change on the basin.

### 2.5 Relevant experience to learn from

Although the situation varies from basin to basin, both in China and in other countries, basin stakeholders are facing increasing challenges from climate change and need to continuously improve and strengthen regional coordination mechanisms to address them. China is strengthening regional coordination of major river basins through a more systematic and comprehensive approach, such as the successive enactment of the Yangtze River Protection Law and the Yellow River Protection Law. The case of the Zambezi River shows that environmental protection goals and reduced impacts on agricultural and energy production in the basin can only be achieved if the basin countries collaborate on activities such as agricultural irrigation and hydroelectric power generation. In addition, long-term planning related to watershed governance needs to be adjusted periodically as physical changes in climate become apparent (See 3.1 "Water and drought disasters are prominent and tend to be extreme").

When designing policies and interventions for watershed governance, they must always be evaluated at appropriate spatial and temporal scales, and all consequences must be assessed in a multi-objective dimension, including the costs and effectiveness, co-benefits, and negative side effects of the interventions. The assessment should consider not only the short-term impacts on river flow and ecology, but also the long-term impacts; the impacts on the surrounding areas need to be considered within the watershed system, not just the local geographical impacts; and the trade-offs between the multi-dimensional objectives of achieving the benefits of engineering measures such as navigation and flood control and maintaining the long-term stability of the river ecosystem should also be taken into account. In order for an ecosystem to be considered stable, it needs to have mechanisms in place that help it return to its original state after a disturbance occurs. According to today's research understanding of the basin, some of the previous large-scale artificial intervention projects in the Rhine basin might not have been implemented.

Changes in basin governance policies are often in response to major events and are abrupt in nature but require advance preparation of policies and plans to promote timely implementation of policies when the window of opportunity comes. The governance history of various major river basins, such as the Yangtze and the Rhine, shows that major shifts in basin governance policies are usually the result of responses to major events in the basin. The IPCC Sixth Assessment Report states that watersheds that are poorly adapted to climate change will be at great risk, and as with watersheds around the world, advance integrated watershed resilience planning is not only necessary to address the multiple and acute impacts of climate shocks on the Yangtze River Basin, but is one of the key government tasks with a great sense of urgency.

Strengthening basin coordination mechanisms at the overall national level or establishing transnational cooperation organizations to develop basin-wide governance plans (or programs) with consensus is central to promoting coordinated regional governance in the basin. The governance experiences of the Yangtze River in China and the Mississippi River in the United States show that national governments can play an important role in coordinating cross-administrative basin issues such as flood control, navigation, and ecological and environmental protection. Transnational rivers such as the Rhine, the Amazon, and the Zambezi have established transnational basin coordination bodies with the participation of the governments of the basin countries.

Increased public participation is important to enhance regional coordination in watersheds. Cases of watersheds such as the Rhine and Mississippi show that the public is increasingly involved in watershed governance decisions at the same time as the challenges facing the watershed are increasing. However, mechanisms and methods to enhance public participation still need to be better studied. Considering the public interest and new ways for the public to access information, judicious use of social media and other modern communication technologies can enhance participation in the work and help facilitate better decision-making in watershed governance.

## 3. Upstream River Section: Analysis and Synergistic Governance Thinking in the Middle and Lower Jialing River Region

### 3.1 Regional Overview

The Jialing River is an important tributary on the left bank of the upper reaches of the Yangtze River. The mainstream of the middle and lower reaches of the Jialing River is 740 km long with a natural drop of 303 m.

The main tributaries in the middle and lower reaches include the Bailong River, Dong River, Xi River, Dui River and Ful River, and the watershed is dominated by low mountains and hills. The major cities in the region are Guangyuan, Nanchong and Guang'an in Sichuan Province and Hechuan, Beibei, Yubei, Jiangbei, Shapingba and Yuzhong in Chongqing.

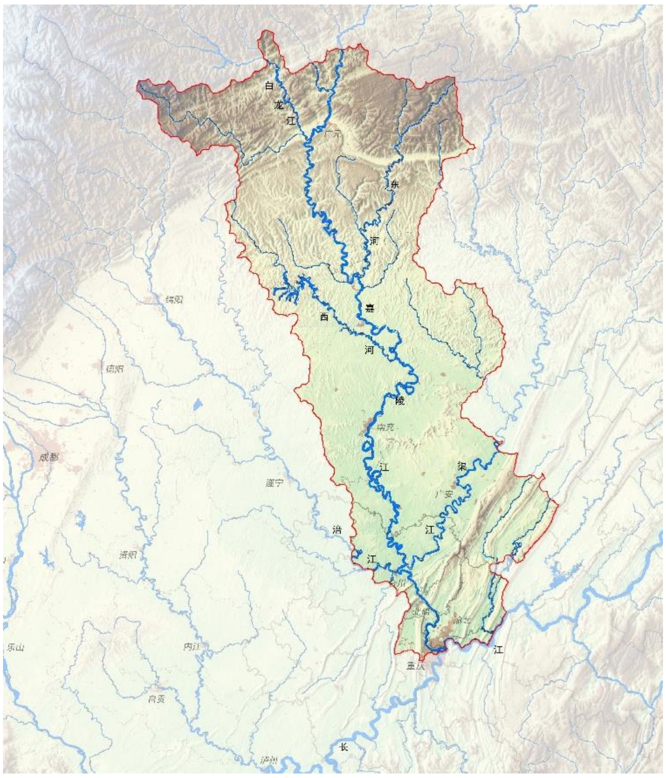


Figure 2 : The three cities in Sichuan province and six districts in Chongqing municipality involved in the middle and lower reaches of the Jialing River

The region is a less-developed area and is in a rapid development stage with an increasing demand for energy, water and other resources. The socio-economic development level of the middle and lower reaches of the Jialing River is low, and the urbanization rate and per capita GDP are lower than the national average. With the accelerated construction of the twin-city economic circle in the Chengdu-Chongqing region, the industrialization and urbanization of the region will accelerate, and the demand for energy, water, and other resources as well as the pressure on carbon emissions will continue to increase.

Water and drought disasters are prominent and tend to be extreme. The middle and lower reaches of the Jialing River are subject to severe flooding due to heavy rainfall areas in western Sichuan and Daba Mountain, with major or very large floods occurring in 2015, 2018 and 2020. Temperature in the basin has increased in recent years, with a warming rate of 0.35°C/10 years after the 1990s, leading to an increase in the number of droughts. From June to August 2022, sunny and hot weather persisted in the middle and lower reaches, with 20%-30% less precipitation than the multi-year average, leading to a bare riverbed in the Chongqing section of the Jialing River. Droughts and floods—and their co-existence—in the middle and lower reaches increase the demand for an integrated scheduling of water resources in the basin.

The region belongs to two provincial-level units, placing higher demands on the synergistic management of the basin. Chongqing became a municipality directly under the central government in 1997, after which the middle and lower reaches of the Jialing River were divided between Sichuan Province and Chongqing Municipality. In 2011, 2016 and 2021, the Regional Plan for the Chengdu-Chongqing Economic Zone, the Development Plan for the Chengdu-Chongqing City Cluster and the Outline of the Construction Plan for the Twin-City Economic Circle in the Chengdu-Chongqing Region were issued at the national level, all requiring to strengthen the inter-provincial synergistic governance of Sichuan and Chongqing in the Jialing River Basin.

### 3.2 Risks and challenges faced

The complexity of the problems brought about by climate change and accelerated development has posed new challenges to the existing integrated watershed management approach. In recent years, the middle and lower reaches of the Jialing River have faced both more frequent heavy rainfall floods and high temperature droughts due to climate change, and accelerated development as a late-developing region has brought more energy and resource demands and environmental pressures. The risks of water security and water shortage in the non-riverine rural areas of the basin are more prominent, the single energy structure dominated by hydropower is challenged by the increased number of droughts, and the organization of water transportation is also facing difficulties in the coordination of multi-stage locks, and the problem of surface pollution caused by agricultural development is further aggravated.

Rural areas are lagging in disaster prevention and mitigation facilities, with high impacts of flood and drought disasters and agricultural pollution. Weak flood-prevention facilities in rural areas lead to rising agricultural losses every year. In 2018, some counties and districts in Guangyuan City were hit by torrential and heavy rainfall, with 122 townships and 58,388 people affected and 63,900 mu of crops affected. In 2021, Nanchong City experienced more than 20 strong rainfall events, and summer and autumn floods caused serious damage to vegetable bases along the river in Nanchong and a significant reduction in vegetable production. Drought caused a reduction in rural food production and difficulties in drinking water for humans and livestock. 2014 summer and fall droughts in northeastern Sichuan caused 70% of corn to go unharvested and 30% of crops to die in Cangxi County, Guangyuan City. The proportion of the population with drinking water difficulties in the basin reached 30% and above, with the elderly and children especially left behind. Water quality is generally improving, but agricultural pollution has become the main source of pollution. In 2021-2022, the water quality of 15 sections of the middle and lower reaches of the Jialing River main stream reached Class III water or more. Water quality is mainly affected by organic pollution composite indicators (CODMn, BOD5, CODCr) and nitrogen and phosphorus (NH3-N, TP). The main sources of pollution are aquaculture, livestock and poultry breeding, agricultural surface sources, and domestic wastewater discharge.

The hydropower industry's ability to cope with high temperatures and droughts is relatively weak, and there is a need to improve the energy mix and increase the resilience of energy supply. The energy structure of the region is dominated by hydropower. In the summer of 2022, the middle and lower reaches of the Jialing River faced the highest extreme heat, the lowest precipitation, and the highest energy demand. These conditions can reduce hydropower capacity by 50%, restricting electricity consumption of cities such as Nanchong along the Jialing River and greatly affecting industrial enterprises and rural vegetables, aquatic products, and fruit freezers.

**Box 3: The impact of high temperature and drought on hydropower energy**

Extreme heat and drought bring great risks and challenges to the hydropower-based energy structure. These challenges include a significant reduction in hydropower generation and a surge in electricity demand due to the high temperature heat wave. In combination, these challenges have a serious impact on regional production and life.

In the summer of 2022, the Sichuan and Chongqing regions suffered from high temperatures above 40 degrees for many days, and precipitation in some areas was 51% less than in the same period in an average year. The middle and lower reaches of the Jialing River faced the highest extreme heat, the lowest precipitation, and the highest electricity demand at this time of the year in history, and the incoming water decreased by 36.4% compared with the same time of the year, resulting in a 50% reduction in daily hydropower generation. The lowest water level of the Tingzikou Hydropower Station reached 438.78 metres, which is close to the dead water level of 438 metres.

At the same time, the heat wave led to a surge in electricity demand. In July 2022, State Grid Sichuan Electric Power sold 29.087 billion kWh of electricity, up 19.79% year-on-year. Among them, the average daily electricity consumption of industry reached 431 million kWh, up 13.11% year-on-year; the average daily electricity consumption of residents reached 344 million kWh, up 93.3% year-on-year.

The decrease in electricity generation was superimposed on the surge in electricity consumption, and urban industrial, commercial and rural production and living conditions were all greatly affected. The electricity consumption of shopping malls, hotels, professional markets, and scenic spots along the Jialing River in Nanchong and other cities was restricted, industrial enterprises used electricity at the wrong time, and some high energy-consuming enterprises stopped production. Rural vegetables, aquatic products, and fruit freezers were affected by power outages and suffered large losses.

To cope with extreme climate, Sichuan and Chongqing regions have been gradually optimizing the energy structure mainly of hydropower by increasing the layout of wind power, photovoltaic, thermal power, and other energy sources and strengthening regional energy coordination. Foreign countries have also taken some measures to cope with the energy risks caused by extreme weather. For example, Hydro-Quebec in Canada released its company-wide adaptation plan in 2021, which includes an equipment modernization program that will increase production by an estimated 5%-10% to help offset declining water levels. This study explores a number of modernization steps, as well as innovative ways to finance upgrades to older hydroelectric equipment.

### 3.3 International Case Study

The Rhine River originates in Switzerland at the northern foot of the Alps and flows through Austria, France, Germany, and The Netherlands before emptying into the North Sea near Rotterdam, The Netherlands. Major interventions were implemented in the 19th and 20th centuries to optimize the economy (with the main aims of flood control and improving shipping conditions). These interventions have—partly unforeseen—long-term, adverse impacts that threaten the river's functions. In order to mitigate these negative impacts, and because of the growing concern for sustainable functioning of watersheds (hydrodynamics, morphology, and ecology), several watershed management plans and governance mechanisms have been established, including the return of land to the river's floodplain, the introduction of integrated river basin management, and the establishment of the International Committee for the Protection of the Rhine (ICPR).

Compared to most large river systems, the Rhine is relatively well-coordinated at the basin scale, as all Rhine riparian countries are committed to the EU directives on ecology, biodiversity, and flood protection and appreciate the functioning of the International Commission for the Protection of the Rhine. Since 2000, the European Water Framework Directive (WFD) gives new impetus to the river basin approach and to international cooperation in European catchments. It aims at transforming mainly water quality-oriented management into the more integrated approach of ecosystem management. It applies to inland, transitional, and coastal surface waters as well as groundwaters. It ensures an integrated approach to water management, respecting the integrity of whole ecosystems, including by regulating individual pollutants and setting corresponding regulatory standards. It is based on a river basin district approach to make sure that neighbouring countries cooperate to manage the rivers and other bodies of water they share.

The Rhine River has the following lessons learned in its management: When intervening in a river system, there is a need to assess the impact on the appropriate scale in time and space (i.e., a scale of expected effects); the need to seek alternatives to infrastructure measures, again, using appropriate scopes and system boundaries; and the need to seek collaboration on appropriate scales (corresponding to the scale of the physical system).

**Box 4: The EU Water Framework Directive**

The EU Water Framework Directive (WFD) is a legislative framework established by the European Union to protect and improve water quality across member states. It sets out a comprehensive approach to water management with the aim of achieving "good status" for all water bodies, including rivers, lakes, coastal waters, and groundwater. The WFD includes:

1. **Objective-Oriented Approach:** The WFD employs an objective-oriented approach, meaning it sets specific goals and objectives for water quality rather than prescribing detailed actions or methods. The primary objective is to achieve and maintain "good status" for all water bodies, which refers to a state where the water environment is healthy, sustainable, and free from pollution or degradation.
2. **Positively Formulated Targets:** The WFD establishes positively formulated targets, which means that the focus is on achieving specific environmental quality objectives rather than merely avoiding negative outcomes. These targets are defined in terms of measurable parameters such as chemical concentrations, biological indicators, and ecological conditions. For example, the targets may include specific levels of oxygen saturation, nutrient concentrations, or the presence of certain species.
3. **River Basin Management:** The WFD adopts a river basin management approach, where water management is organized at the river basin scale rather than being fragmented by administrative boundaries. Member states are required to establish River Basin Management Plans (RBMPs) that outline the objectives, measures, and targets for each river basin district within their jurisdiction. These plans involve extensive stakeholder engagement and public participation to ensure a participatory and inclusive decision-making process.
4. **Monitoring and Assessment:** The WFD emphasizes a robust monitoring and assessment regime. Member states are required to monitor the status of their waterbodies and periodically assess their ecological and chemical conditions against the established objectives and targets. This monitoring

and assessment process provides a scientific basis for evaluating progress, identifying areas of concern, and informing the development of appropriate measures to achieve the objectives.

5. **Program of Measures:** To achieve the WFD's objectives, member states develop and implement a Program of Measures as part of their RBMPs. These measures encompass a wide range of actions, including pollution prevention and control, habitat restoration, water efficiency improvements, and public awareness campaigns. The measures should be cost-effective, technically feasible, and implemented within specified timeframes. The Water Framework Directive (WFD) plays a crucial role in addressing issues between upstream and downstream regions and promotes a sense of unity among nations sharing river basins. By equalizing the status of upstream and downstream countries, the WFD imposes new responsibilities on downstream states. In accordance with an ecosystem approach, the actions taken by downstream nations also become increasingly significant. For instance, they must implement measures to facilitate the migration of fish species to upstream areas of river systems. The WFD prioritizes the well-being of fish populations as they serve as vital indicators of ecological health. The European Commission assumes a new role in overseeing and monitoring river basin management, fostering greater cooperation and solidarity among basin states. To achieve improved water quality and address upstream-downstream challenges, economic instruments can be employed, and the WFD allows for the possibility of financial compensations, provided that the polluter pays principle is upheld.

6. **Review and Reporting:** The WFD requires periodic review and reporting to assess the effectiveness of measures and progress toward achieving the objectives. Member states report on the status of their water bodies, the implementation of measures, and the overall effectiveness of their RBMPs. This reporting facilitates accountability, knowledge exchange, and the sharing of best practices among member states.

By adopting an objective-oriented and positively formulated approach, the EU Water Framework Directive provides a framework for member states to work toward the sustainable management and improvement of water quality, promoting a holistic and integrated approach to water management across Europe.

### 3.4 Collaborative governance mechanisms for improving basin resilience

*Past interventions and their effectiveness*

In 1986, the Jialing River started the construction of the first terrace Mahui Power Station, and in 1999, the Sichuan Provincial People's Government approved the implementation of the "Jialing River Drainage Planning Report," which took into account flood control, water conservancy, hydropower, and water transportation factors, and planned the construction of interconnected terrace navigation and power projects from Guangyuan to Chongqing. At present, 15 step hubs have been completed (14 in Sichuan and 1 in Chongqing), 1 is under construction (Chongqing Lize Hub) and 2 have not yet been built (Chongqing Jingkou and Sichuan Guangyuan Shidongba Hub).

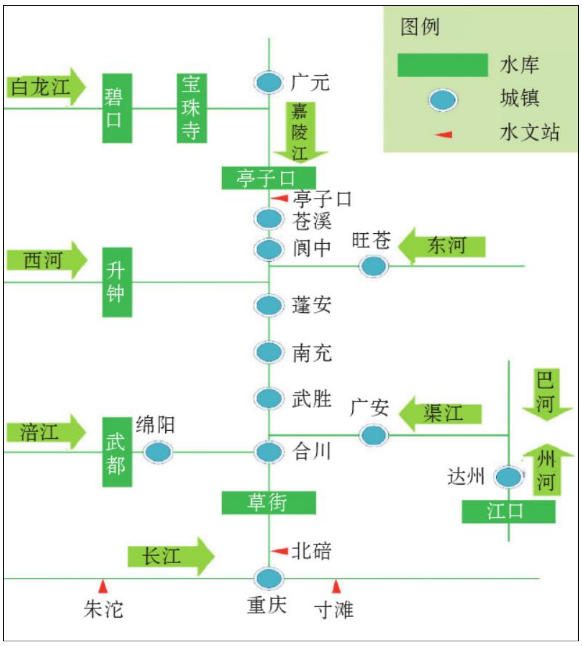


Figure 3: Flood control-related reservoirs and objects in the middle and lower reaches of the Jialing River

The water conservancy projects have improved the flood control conditions of cities along the river and promoted the development of hydropower and shipping. The flood control standard of cities (counties) along the river such as Nanchong and Langzhong has been raised to one in 50 years, and the flood control standard of downstream towns (towns) and farmlands along the river is merely equivalent to one in 5-10 years. The hydroelectric project has provided a lower cost and sufficient supply of hydropower to cities along the river, stimulating the development of high energy-consuming industries. The entire middle and lower reaches of the Jialing River have been canalized, and the navigability has been significantly improved. It is one of the 18 high-grade waterways approved by the state, and the cost of waterway transportation on the Jialing River is only 0.08 yuan/ton kilometre, which is 46% of the price of railroad transportation and 23% of that of roads, and has the potential to build a new channel connecting the northwest and the middle and lower reaches of the Yangtze River.

The hydroelectric projects bring certain ecological and environmental impacts, and the low price of hydropower leads to structural risks of high energy-consuming industries and insufficient improvement of non-riverine rural areas in the basin. As a result of the implementation of the stepped navigation and power project and human activities, the watershed environment of the Jialing River has been damaged to a certain extent. The ecological flow in the downstream section of the river is insufficient, the aquatic plant system and biological population structure have been affected, and the migration and spawning paths of rare fish such as coelacanth have been blocked, resulting in a decline in the number and diversity of fish. In recent years, high temperatures and drought in summer have resulted in insufficient hydropower supply and widespread power restrictions and shutdowns in industries along the river. The construction of water conservancy projects has improved the flood control and water supply conditions of towns along the river, but the water supply coverage of non-riverine areas, especially rural areas, is insufficient, and the resistance to climatic disasters, such as high temperature and drought, is more vulnerable.

Table 2: Irrigation area and proportion of newly cultivated land irrigated in the three cities of Sichuan province

| | 2018 | | | 2010-2018 | | |
|---|---|---|---|---|---|---|
| | Cultivated land | Irrigated arable land | Proportion of irrigated area to cultivated land | New arable land | New area of arable land irrigated | New irrigated area |
| | thousand hectares | | % | thousand hectares | | % |
| **Sichuan Province** | **6723** | **2992** | **45** | **2712** | **439** | **16** |
| *among which:* | | | | | | |
| Nanchong | 534 | 235 | 44 | 233 | 28 | 12 |
| Gwangan | 308 | 108 | 35 | 134 | 13 | 9.5 |
| Guangyuan | 353 | 95 | 27 | 187 | 7.2 | 3.8 |

Source: Sichuan Statistical Yearbook

The middle and lower reaches of the Jialing River have initially established a coordination mechanism for flood and drought prevention and control. Sichuan and Chongqing have developed mechanisms such as "Sichuan Jialing River Basin Flood Control Consultation System," "Sichuan Jialing River Basin Flood Information Transmission System," and "Memorandum on Information Sharing and Reporting for Water and Drought Disaster Prevention and Control in Chengdu-Chongqing Economic Zone." Sichuan and Chongqing share rainfall and water information from nearly 100 stations and conduct joint reservoir scheduling in response to floods.

The basin governance faces synergy challenges in multiple fields such as shipping, flood control, drought relief, and hydropower generation. These are challenges among governments, departments, and multi-stakeholders between governments and enterprises, and between main stream governance and development needs of rural areas. At present, the Jialing River obeys flood control scheduling during flooding periods and mainly obeys power scheduling during non-flooding periods. Influenced by the security of the power grid system and fluctuations in peak and valley power demand, the flow rate in the reservoir area may rise and fall steeply, and the water level may rise and fall steeply, posing certain risks to navigable vessels. The increase in extreme weather due to climate change makes it more difficult to synergize multiple areas such as shipping, flood control, drought relief, and hydropower generation.

The water conservancy hub in the middle and lower reaches involves six owners, the government involves two provinces (cities), six cities (districts), and several county-level units, and the departments of water conservancy, energy, transportation, flood control, and environment are involved in the management of the basin, making the synergy between the two provinces, between departments, and between the government and enterprises increasingly difficult. After the construction of water conservation projects, flood control, water supply, and navigation conditions in the near-shore areas of the main stream have been improved, and the socio-economic development gap between the vast countryside of the inland hinterland has increased, requiring further strengthening of regional coordination.

*Importance of collaborative governance mechanisms for resilience*

The future development of the middle and lower reaches of the Jialing River faces extremely complex challenges, both in terms of regional security, environmental protection, and control of energy consumption and carbon emissions due to climate change and in terms of meeting the resource and energy needs resulting from rapid development. Europe has made strategic environmental impact assessment a prerequisite for synergistic watershed management, with good results. In China, the synergistic management of watersheds is more complex and requires synergies in flood, drought, flood control, power generation, urban and rural water security, navigation, and biodiversity, etc. The following specific measures are needed to develop "multi-objective integrated solutions."

**Transform the economic and social development mode and explore the path of regional economic and social development with low energy consumption and low water consumption.** Implement the requirements of "Yangtze River Protection," promote green and low-carbon production and lifestyle, and pay attention to the unstable energy supply and demand in summer brought by high temperatures and drought on the basis of green hydropower as the leading one. Moderate adjustment of industrial structure and gradually limit the development of metal smelting, chemical, non-metallic minerals and other high-energy-consuming industries in the basin. Strengthen the joint transfer and supply of electricity with neighbouring provinces and western Sichuan, accelerate the construction of foreign power into Sichuan and Chongqing channels, and the power supply of northwestern provinces, water and light power supply in Tibetan areas to form a complementary, enhanced inter-provincial diversification, multi-directional mutual aid capacity. Encourage the development of wind power, photovoltaic, and other renewable energy, moderate development of local resources advantages of natural gas and other clean energy, and modestly enhance the peak topping capacity of coal power.

**Establish a synergy mechanism between governments, departments and enterprises, and between the river and the hinterland, taking into account multiple objectives and multiple interests.** In the face of the multiple challenges posed by climate change, it is necessary to synergize multiple objectives, such as power generation, flood control, drought relief and navigation, and to strengthen multi-level and multidisciplinary synergy. Promote the Yangtze River Commission to move from relatively single control of the water system to multi-objective management and response to the demands of multiple interests to establish corporate interests. Explore the establishment of synergy and negotiation mechanisms between provincial governments, city governments, and authorities in different regions. Strengthen the synergy between the governments of Sichuan and Chongqing at all levels. The provincial level focuses on establishing a unified and collaborative scheduling mechanism for the basin, coordinating flood control, drought relief, power generation, and shipping management, developing a unified governance framework and assessment and monitoring indicators, and the municipal level focuses on controlling disaster risks between local counties (cities) and between cities and villages to guide the transformation of economic and social development patterns. Strengthen the synergy between the government and water hub enterprises, focusing on coordinating the joint scheduling of water resources for power generation, navigation, and flood and drought control. Study the establishment of a mechanism for the transmission and feedback of interests of grassroots rural units, and study the mechanism for linkage development and transfer payments between the agricultural areas along the river and the hinterland.

**Focusing on non-riverine rural areas, localized, natural, low-impact rural governance approaches need to be explored.** Learn from history, adopt natural solutions as much as possible, and fully study the contemporary value of the historically formed "mound, pond, and forest" settlements and agricultural systems. Protect and restore the weir and pond system to build a green and resilient ecological base for the countryside. The weir and pond system is a traditional ecological wisdom in Sichuan and Chongqing regions. Villagers make fields at the bottom of the mound, build ponds at the water catchment, and plant forests at the top of the mound, which is a restrained use of land, vegetation and water resources, and has multiple functions such as rainwater storage, drought and flood regulation, rural biodiversity protection, and water purification. Combining the construction of irrigation canals and natural streams and ditches, we can build small rural wetland groups to improve the self-purification capacity and environmental capacity and enhance rural biodiversity. Develop a three-dimensional, composite rural industry of "agriculture-wet-fruit-raising-tourism." development model. In the "mound bottom rushing field," we implement the construction of high-standard farmland, guide the rotation of grain and vegetables, and encourage "rice and shrimp," "rice and fish," and other compound agricultural methods; in the "mound foot Village Settlement" to improve the quality of services and environment, and encourage the integration of agriculture and tourism; "Hillside Dryland" to guide the integration of farming and development of "pig–swamp–fruit/vegetable "The "top of the hill" promotes the naturalization of planted forests, nourishes water and soil, and creates rural leisure landscape areas.

**The water conservation hub projects in the middle and lower reaches of the Jialing River that have not yet been constructed should be reassessed.** One reason is to assess the changes in the construction conditions of water conservancy projects brought about by the expansion of urban construction land, the second is to assess the impact of water conservancy projects on urban safety and accident risks, the third is to assess whether it is conducive to the improvement of the regional energy structure, and the fourth is to assess the ecological and environmental risks brought about by the construction.

**Box 5: Settlement and Agricultural System in the Jialing River Area**

The Jialing River basin is a hilly area, which naturally forms a "mound, pond, and forest” settlement and agricultural system, consisting of mounds, ditches, weirs and ponds, wastelands, drylands, woodlands, farm houses, dams, and roads, etc. It has the characteristics of "mound bottom wasteland, mound foot village, mound slope dryland, mound top woodland." The system is vertically stratified. This system has an important role in coping with rain and flood storage, drought and flood regulation, etc.

Mound Pond: The seasonal distribution of precipitation in the watershed is uneven, and there is a problem of soil erosion in the hilly areas. To solve the irrigation problem, people build semi-enclosed dikes and weirs to form weirs or ponds in the process of land development in hilly areas, taking into account the topography. This is a semi-artificial water conservancy engineering technology, with the power of nature, to store rainwater during rainfall, play the role of rain and flood storage, drought and flood regulation, and at the same time to support a variety of aquatic plants and animals, purify water quality, perform production and ecological functions, in one fell swoop.

Mound field: Mound bottom wash field. Alluvial ditch is the area where rainwater collects in the hilly area. Under the effect of alluvial accumulation over the years, the topography is gentle, the soil is thick and the fertility is high, which is convenient for cultivation and drainage, and it is a high-quality area for agricultural production in the hilly area of Sichuan and Chongqing. Hillside Dryland: The relatively large slope of the mound hill, as well as the difficulty of hoarding and storing water, has been developed by local residents into a diversified complex agriculture of dry farming or planting forest fruits and taking into account forest farming.

Mound forest: The tops of mounds and steeper slopes are woodlands in clusters or strips, which play the role of water conservation and soil preservation. Native species of trees such as cichlid bamboo are planted around farmhouses to provide shelter for residential houses and create a shady microclimate and rich landscape.

Mound dwelling: The farmhouses are distributed at the foot of the mound, built on the mound and adjacent to the fields, with a scattered layout near the road, avoiding the risk of flooding and facilitating agricultural production and labour.

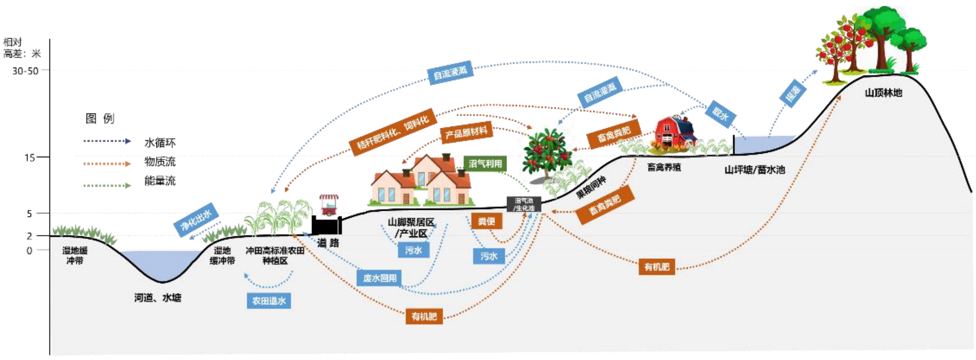


Figure 4: Conceptual diagram of comprehensive three-dimensional development in agricultural and rural areas of the watershed

## 4. Great Lakes Basin: Analysis and Collaborative Governance Thinking in the Taihu Lake Basin

### 4.1 Regional Overview

Taihu Lake Basin is located at the mouth of the lower reaches of the Yangtze River, involving three provinces and one city, Jiangsu, Zhejiang, Shanghai, and Anhui, with a basin area of about 36,900 square kilometres, a resident population of about 68.11 million in 2021, and a population density of 1,846 people/km$^2$, equivalent to 3.5 times that of The Netherlands; a regional GDP of about 112,736 billion yuan, and a per capita GDP of 165,000 yuan, equivalent to the national average. It is a typical delta region with high population density, high economic vitality, and high intensity of land development.

The topography of Taihu Lake Basin is a disc-shaped terrain with a high periphery and low middle. The general topography is high in the west and low in the east. In 80% of the plain area, the elevation is generally below 5 metres, and more than half of the ground elevation is lower than the flood level. The current water surface area of the basin is about 5,551 square kilometres, the water surface rate reaches 15.0%, equivalent to 1.5 times The Netherlands. In the period of ancient agricultural society, the water problems in Taihu Lake Basin were mainly floods and droughts. Nowadays, there has been a tight balance between human activities, land development and water management, resulting in a comprehensive and complex water problem where water disasters, water environment, and water ecology coexist and intertwine. Therefore, this report focuses on synergistic management of watershed flood safety and synergistic management of agricultural surface source pollution.

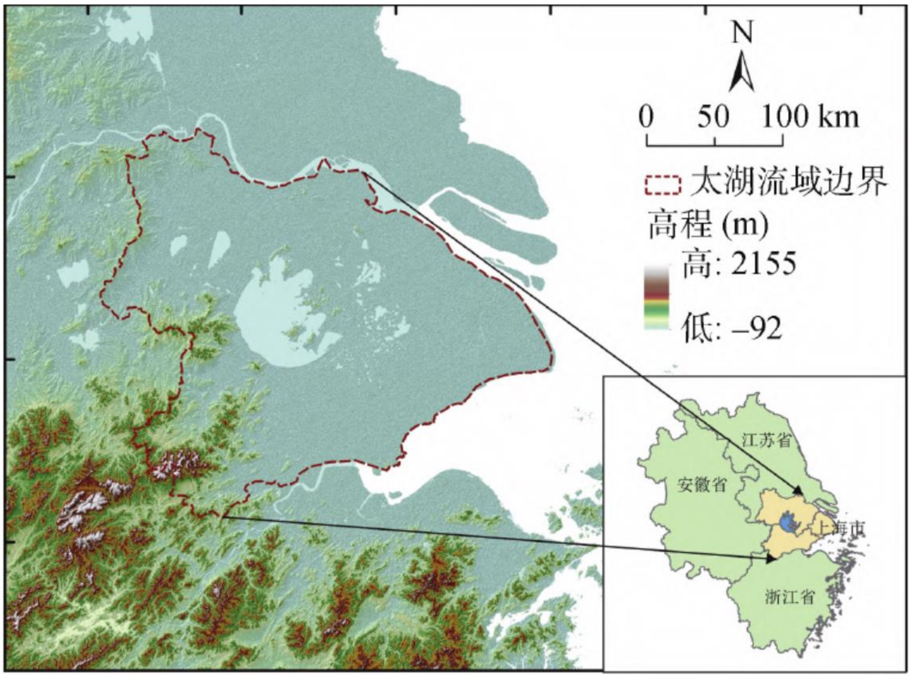


Figure 5: Taihu Lake Basin

*History and effectiveness of collaborative flood safety management*

**The watershed flood control engineering system has been gradually established, relying mainly on the backbone river flooding.** In 1991, a huge flood occurred in Taihu Lake Basin. The total precipitation in the basin reached 514.4 mm in June–July, and the water level in Taihu Lake reached a maximum of 4.78 metres, with the number of days exceeding the warning level reaching 47 days. Direct economic losses were 11.39 billion yuan, accounting for 6.8% of the basin's GDP that year. In order to promote the comprehensive management of Taihu Lake Basin, in September 1991, the State Council held a meeting on the governance of Huaihuai and Taihu, made a decision on the comprehensive management of Taihu Lake, approved the implementation of the "Overall Plan for the Comprehensive Management of Taihu Lake Basin," 11 backbone projects for the comprehensive management of the basin (a round of treatment of Taihu), and 21 backbone projects for the comprehensive management of the water environment in the basin (the second round of treatment of Taihu) were implemented one after another, laying a three-way drainage pattern in the Taihu Lake Basin and initially the basin flood control and water resource control engineering system has been formed. Among them, four projects, including Tai Pu River, Wang Yu River, Hangjia Lake South Drainage and Lake Ring Dike, are World Bank flood control projects for Taihu Lake, which is the first cross-province (municipality directly under the central government) flood control project in China with World Bank loans.

**Urban flood control to large polder areas as a unit and consantly expand the scope of the polder and defence standards.** Through the small polder into large polder, the flood control standard of important cities in the basin basically reached 50 years and above, Suzhou, Wuxi, Changzhou and other urban centres flood control standard of 200 years, a single large polder area from 10 to 20 square kilometres of expansion to 50–150 square kilometres today, the drainage modulus of $3m^3/s/km^2$ above, is the average drainage 2.1 times of the average flooding level in the basin. The construction of the Taihu Lake Urban Flood Control Polder has to some extent improved the standard of flood control in the urban centre and low-lying areas.

**Preliminary completion of the basin scheduling system and implementation of graded scheduling in different time periods.** In the face of excessive floods in Taihu Lake, the Taihu Bureau, together with the provinces (municipalities directly under the central government) in the basin, based on the "Taihu Lake Basin Flood and Water Scheduling Plan," "Taihu Lake Basin Water Allocation Plan," and other scheduling documents, focused on improving infrastructure, integrating system resources, promoting information sharing and deepening business applications, dispatched backbone water conservancy projects in different time periods and built the "Smart Taihu Lake "system. At present, the system has made partial achievements in basin information sharing, integrated monitoring and early warning, scheduling decision making and comprehensive supervision, realizing a certain degree of wisdom.

*History and effectiveness of agricultural surface pollution management*

**After the outbreak of cyanobacteria, the government began to implement a comprehensive management program for the water environment in the Taihu Lake Basin.** In 2007, a large-scale cyanobacteria outbreak in Taihu Lake led to a water supply crisis in the region, which seriously affected the normal life of the local people and aroused widespread concern in the whole society. In 2008, the State Council approved the "Overall Plan for the Comprehensive Management of the Water Environment in Taihu Lake

Basin," which clearly put forward the two goals of ensuring the safety of drinking water and ensuring that no large area of black water odour occurs.

The joint meeting system has been established with multi-party collaborative comprehensive management, improving legislative protection. In 2008, the National Development and Reform Commission (NDRC) took the lead, and relevant departments and three provinces and municipalities participated in the joint provincial-ministerial meeting system for the comprehensive management of the water environment in the Taihu Lake Basin. In 2011, the Ministry of Water Resources, the Ministry of Environmental Protection, and the State Council Legislative Office jointly issued China's first comprehensive administrative regulation, "Regulations on the Management of Taihu Lake Basin," and took the lead in establishing and improving the five-level river and lake governor system at provincial, municipal, county, and village levels, building a platform for a collaboration mechanism between the governors of Taihu Lake and Dianshan Lake, and vigorously promoting pesticide and fertilizer use reduction, and rectifying illegal farming near the Taihu Lake, Ge Lake, and other rivers and lakes.

**Comprehensive management of the water environment has achieved initial results, including a significant improvement in the basin water quality.** In recent decades, with the joint efforts of all parties, the comprehensive management of the water environment in the basin has achieved phased results, drinking water safety, pollution prevention and control, cyanobacteria prevention, and ecological restoration and other key tasks continue to advance; the total amount of pollutants into the lake has been significantly reduced, and the quality of the water environment has been gradually improved.

### 4.2 Risks and challenges faced

*Flood Safety*

Due to the rapid development of industrialization and urbanization, the proportion of hardening of the basin's subsurface—and hence the occurrence of urban flooding—has increased. In addition there is the impact of sea level rise, ground subsidence, storm surge flooding, etc. Overall, the possibility of extreme events in the basin causing disasters is on the rise.

**The sub-basin conditions of the basin have changed significantly, and the storage capacity has weakened.** With the continuous urbanization process in Taihu Lake Basin, the area of construction land increased by 55.59% and 39.98% in the two phases from 2000 to 2010 and 2010 to 2020, respectively, while the area of arable land decreased by 11.66% and 18.56%, respectively. The rapid expansion of construction land leads to an increase in the percentage of impervious area in the whole Taihu Lake Basin, a decrease in storm water infiltration, an increase in flood runoff, and an acceleration of flood confluence, which increases the risk of flooding.

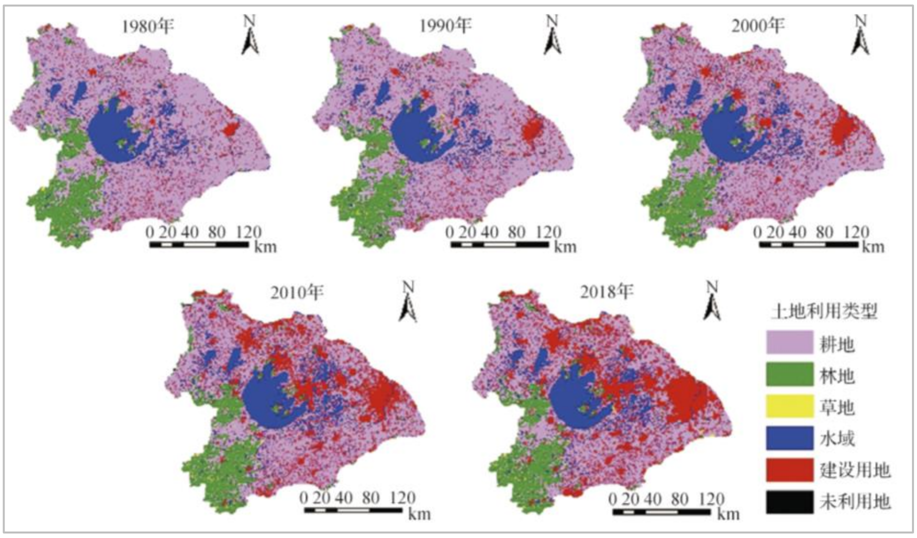


Figure 6: Changes in land use types in the Taihu Lake Basin

**The lack of coordination in the construction of urban polders has led to increased difficulty in flood scheduling.** Currently, in more than half of the plain areas in the basin, polder protection infrastructure has been built, with a total of about 4,160 polder areas. Compared with 1997, the polder area increased from 14,541 km$^2$ to 16,434 km$^2$ in 2015, doubling the total polder drainage power. In addition, because the polder area is generally under the jurisdiction of the town and street, the level of intelligent scheduling is weak, and it is difficult to coordinate in real time at the basin level, which can easily lead to a large number of polder area outflow to the outer river network during the flood season, accelerating the speed and magnitude of the rise of the outer river level, thus limiting the flooding capacity of the backbone river in the basin, which in turn inhibits the urban polder area outflow capacity.

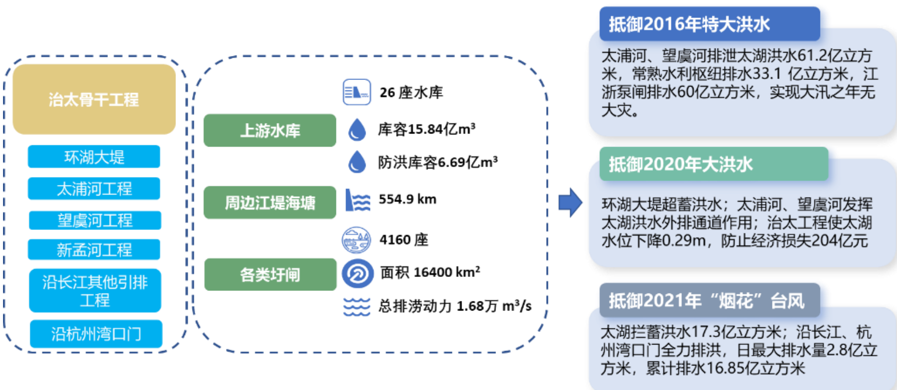


Figure 7: Flood control engineering system in the Taihu Lake Basin

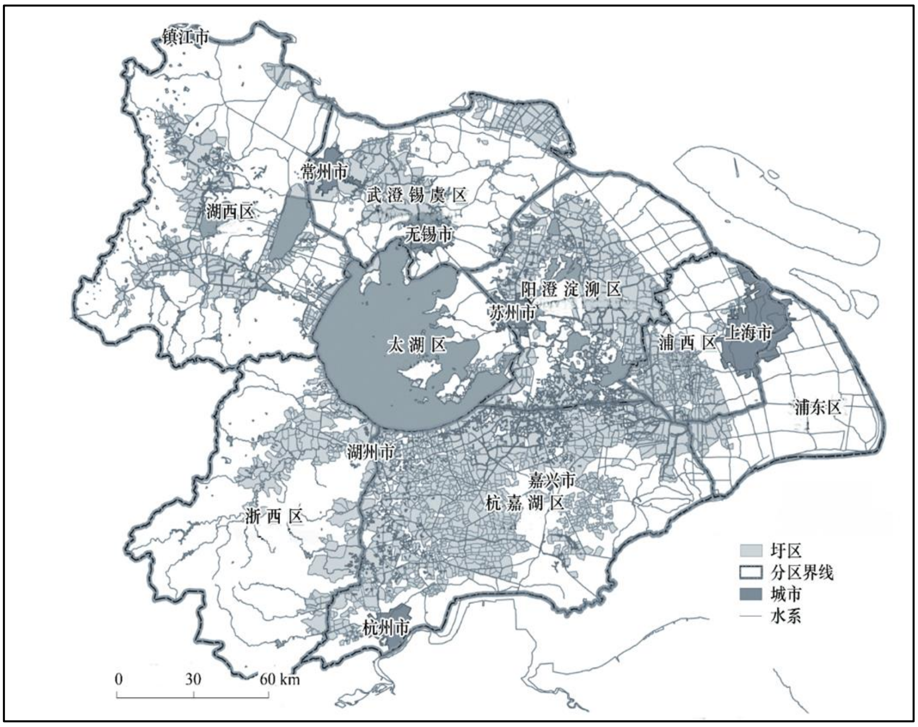


Figure 8: Spatial distribution of polder areas in the Taihu Lake Basin

**Extreme rainfall events and sea level rise will further test the basin's ability to discharge and refine the level of prevention and control.** In recent years, affected by climate change and sea level rise, the tide level of the Huangpu River is trending higher, while extreme weather is frequent, and the basin has an increasing probability of experiencing "four-touch" compound events (simultaneously encountering typhoons, rainstorms, floods, astronomically high tides), and the problem of insufficient pumping capacity along the river and Hangzhou Bay. The problem of insufficient pumping capacity along the river and Hangzhou Bay has become more prominent. In addition, sea level rise and ground subsidence will increase the difficulties of drainage in coastal cities, so that the head of drainage pumping stations will increase and drainage capacity will decrease. In Shanghai, for example, it is expected that by 2030, the relative sea level at Wusong Station will rise by about 16 cm compared to 2010, which is expected to affect 2% to 3% of the total urban drainage, making the past surface source pollution control standards obsolete.

*Agricultural surface source pollution*

As Taihu Lake is a typical dish-shaped lake with limited water environment capacity and insufficient self-purification ability, and considering the developed agriculture in the basin, the input load of nitrogen and phosphorus and other nutrients is large. In the context of global warming, the risk of cyanobacterial blooms is high.

**Nitrogen and phosphorus pollutants into the lake remain high. Agricultural surface pollution has become the most important source of pollution in the Taihu Lake Basin.** In recent years, although the water quality of Taihu Lake has improved after the improvement of point source pollution around the lake, and has basically realized the decoupling from urban living pollution and industrial pollution, the nitrogen and phosphorus elements of the lake are still too high, and the "hotbed" of cyanobacterial outbreaks is still there. Failing to solve the problem of water quality deterioration at source, agricultural surface pollution has become the main source of eutrophication of the water body of Taihu Lake. In 2020, the water quality of Taihu Lake will be surface water category IV, jumping from the poor category V in 2007, but in the assessment of four major water quality indicators: potassium permanganate index, ammonia nitrogen, total phosphorus, and total nitrogen, total phosphorus still fails to meet the control target, and total nitrogen still fails to meet the standard in some months—which is 3.7 times the pollution absorption capacity; total nitrogen is 38,466 tons, which is 4.5 times the pollution absorption capacity. Therefore, the total amount of pollutants entering the lake far exceeds the pollution-absorbing capacity of Taihu Lake, which is the fundamental reason why the water quality of Taihu Lake can hardly reach the treatment target.

Table 3: Pollution loads to Taihu Lake Basin

| | COD | Ammonia nitrogen | Total Nitrogen | Total phosphorus |
|---|---|---|---|---|
| | thousand tonnes | | | ton |
| Industrial point sources | 140 | 11 | 41 | 515 |
| Urban domestic sources | 155 | 15 | 33 | 1978 |
| Agriculture (crops) | 74 | 5,4 | 15 | 1022 |
| Livestock and poultry farming | 130 | 9,6 | 27 | 2074 |
| Rural domestic sources | 61 | 4,8 | 12 | 753 |
| Aquaculture | 48 | 1,1 | 4,3 | 679 |
| Urban non-point sources | 22 | 0.8 | 3.0 | 830 |
| **Total** | **630** | **48** | **135** | **7851** |

**Global warming will cause the lake to warm up and accelerate the expansion of cyanobacterial blooms.** From 1958 to 2017, there was a significant increase in temperature in the Lake Tai basin, with an average temperature increase of 0.293 ℃ per decade, which led to the expansion of cyanobacterial blooms in Lake Tai from the initial concentrated outbreak in summer to spring and autumn, with an earlier outbreak time and longer duration. In addition, the overall trend of precipitation in Taihu Lake Basin is increasing, with an average annual precipitation tendency rate of 3.026 mm/decade, and a significant increase in precipitation in the eastern region and Wuxi and Changzhou areas. During heavy rainfall events, especially extreme rainstorms, nitrogen and phosphorus losses from farmland all increased significantly with increasing rainfall intensity. Precipitation carries nutrient salts and suspended matter into watershed waterbodies through scouring action, which will further increase nutrient loads to rivers and lakes.

### 4.3 International Case Study

In response to the flooding event of the Southern Sea (Zuiderzee), Lake IJssel in the Dutch Rhine river system was created in 1932 by damming this inland sea (connected to the North Sea) with a 32-km long closure dike. The main reasons for this intervention were the prevention of flooding (shortening of the coastline), the possibility of developing land reclamation and the fresh water supply (supporting national agricultural goals, especially after the Second World War). After World War II, the new province of Flevoland, created in The Netherlands on reclaimed land around the lake, developed agriculture according to local conditions. From the

1970s onwards, housing and recreation (forest/natural areas, water recreation) also became important functions in Flevoland.

In the face of climate change, Lake IJssel is becoming increasingly important as a freshwater buffer (in times of drought) and as a water storage area (in times of flooding). In terms of flood protection, climate change is expected to lead to an increase in peak discharge from the Rhine, while higher sea levels will eventually mean that the water of the Rhine can no longer be drained through this lake into the North Sea by gravity alone. This means that more water will have to be temporarily stored in lakes or pumped out into the North Sea. In addition, space requirements or more land reclamation could lead to a reduction in the functional surface area of the lake, increasing the risk of flooding and the probability of water shortages. This space requirement comes from recreation, navigation, housing, and renewable energy production.

Therefore, due to climate change and spatial scarcity, the pressure on the system from different users in and around Lake IJssel is increasing, and stakeholders at the local, national, and even international scales need to work together at these different spatial scales to balance these interests. For example, at the national level, freshwater allocation in times of high discharge and strategies to cope with climate extremes must be developed. The initial strategy developed by The Netherlands is to further strengthen the existing flood protection engineering system to ensure that the mean winter water level of Lake IJssel can be controlled from rising until 2050; after 2050, the lake level will be allowed to rise by 30 cm; however, the impact of rapid sea level rise and further coping strategies are currently still under study.

In terms of agricultural nitrogen and phosphorus pollution, the creation of Lake IJssel has had some negative ecological consequences, with algal blooms and stratified/anoxic zones when tidal seawater becomes a stagnant freshwater lake. In response to water quality issues and adaptation to climate change, EU regulations require a new agricultural transition toward less intensive and more regenerative methods, with less environmental impact in terms of emissions and allowing more biodiversity, now addressed by reducing phosphate emissions.

### 4.4 Collaborative governance Mechanisms for Improving Basin Resilience

*Transforming urban-regional development, carrying out regional subsurface control, and improving the overall safety and resilience of the watershed*

To implement the new requirements of ecological civilization, densely populated and economically dense areas, such as the Taihu Lake Basin, should properly handle the relationship between people and nature. From the perspective of watershed security and resilience, priority should be given to the protection of non-construction space such as arable land, garden land, forest land, and water area, and the proportion of the area's buffer area should be regulated to a reasonable range by strictly controlling the scale of new construction land and "returning land to water" ( restrictions are identified based on areas of ecological importance, current levels of urban congestion, pollution runoff, etc.).

At the national level, a more balanced regional development policy should be introduced to control the intensity of territorial space development in areas with tight resource and environmental constraints, and encourage the transfer of general manufacturing and service industries to the central and western regions. The

Taihu Lake Basin region should effectively change its economic growth mode, rely on innovation to improve total factor productivity, and take the new urbanization path of spatial intensification, industrial efficiency and green and low-carbon development.

*Strengthen the integrated management of flood risks in the basin, the implementation of polder refinement linkage management, strengthen upstream and downstream cooperation in flood control*

**Optimize the polder construction mode, the implementation of polder refinement linkage management.** In terms of polder construction level, it is recommended to restrict large-scale joint polder and polder projects in the basin, strict control of new polders, and avoid building polders in the semi-upland. Before adding polder areas, carry out flood risk analysis along with moderate reduction of low-risk polder construction standards. Polder management level should be coordinated with the relationship between water levels inside and outside the polder to ensure the safe operation of urban polder, moderate reduction in pumping power, slowing the rate of rise of water levels outside the polder.

**Strengthen flood control cooperation in the basin and improve the upstream and downstream synergy-feedback mechanism.** In the face of severe challenges brought by climate change, the model of relying on each administrative region alone for flood control and management is unsustainable. Combining with the experience of cross-industry cross-regional coordination mechanism of Lake IJssel in The Netherlands, it is suggested to accelerate the establishment of a basin-regional coordination mechanism in the Great Lakes region, cooperate in the construction of flood control coordination zones, integrated management of flood control and drainage, etc. For major projects in dispute, the scheduling authority can be handed over to the basin management agency for unified scheduling.

**Collaborate to build a smart water network in the basin and improve the level of engineering scheduling and risk warning.** Promote the deep integration of advanced information technology and water business, realize the change from water and rain forecasting to flood impact and disaster risk forecasting, and improve the level of information openness; strengthen the cooperation and exchange of monitoring and early warning between basin agencies and related cities in the field of water safety and security by opening up the smart water platform at different levels of the basin, and improve the flood control decision-making command system.

*Protect and utilize the great heritage of agricultural water conservancy and natural wetland resources, shape the urban and rural ecological space of Tangpu Polder, and promote natural solutions*

**Establish an ecological buffer zone around the lake to enhance the ecological value and social value of natural resources.** A certain range of the land area around the lake is designated as the ecological buffer zone of the Great Lake, and corresponding control measures are formulated to protect the most sensitive water–land interface area of the ecological environment around the lake, which is conducive to not only alleviating cyanobacteria and other water environment problems but also improving the storage and purification capacity of the ecological space around the lake.

**Strengthen the control of transboundary rivers and lakes, and gradually restore the basin water storage space.** Develop a coordinated management plan for transboundary river and lake spaces in the basin, protect and moderately restore the core water surface, restore natural habitats, and enhance water storage and drainage functions by retiring fishing to the lake, retiring dikes around the lake, and dredging major inlet and outlet rivers.

**Learn from history and promote the protection and utilization of water cultural heritage with high quality.** It is proposed to draw on the experience of the Taihu Lake Basin's management of graded control, storage and stagnation, diversion, and drainage, and to link the basin's water management and polder management to the overall planning. Maintain the originality, integrity and continuity of the Great Lakes water cultural heritage.

**Respect site characteristics and carry out low-impact development and construction with the polder as a unit.** Control rainwater runoff at the watershed and urban scale, build sponge cities, reduce the pressure on urban pipe networks, and increase the storage capacity of runoff rainwater that exceeds the discharge capacity of pipes and drains within the urban area. Strengthen the protection of urban water system veins and minimize the disturbance to the existing water system space.

*Promote the integration of modern agriculture, collaborate to carry out joint treatment of pollution and carbon reduction, and manage agricultural surface pollution through scientific and technological innovation*

**Promote green production methods in agriculture, and collaborate to promote pollution and carbon reduction.** Focus on chemical fertilizers and pesticides, crop straw, and farming pollution as the three key points. Promote regenerative agriculture and other natural farming methods, implement chemical fertilizer and pesticide reduction and efficiency actions, and improve the efficiency of nitrogen and phosphorus fertilizer utilization; improve the level of comprehensive utilization of straw, and strengthen the control of straw burning; promote the resource utilization of livestock and poultry manure, and the construction of ecological breeding of rice and fishery, and reduce carbon emissions in key breeding links.

**Improve access to green and low-carbon agricultural industries and strengthen the leadership of science and technology innovation in agricultural surface source pollution control.** According to the 2017 State Council's Opinions on Innovative Institutional Mechanisms to Promote Green Development in Agriculture, a negative list implementation system for agricultural industry access was constructed and a collaborative and linked implementation mechanism was established at all levels of government. Meanwhile, relying on the scientific and technological innovation platform in the Taihu Lake Basin area, we will strengthen the promotion and application of advanced technologies and scientific and technological innovation results, such as the major special project on agricultural surface source pollution control in water bodies.

*Establish ecological compensation mechanisms for watersheds in economically dense areas and diversify funds to protect watershed management*

**Establish a watershed water fund to share ecological benefits.** The downstream gets clean water and pays the upstream to support the pollution remediation action in the upstream area. Over and above this, establishing a "water fund" trust can guide multiple parties to participate in the protection of water sources and share the benefits, such as developing green industry, building nature education, ecological agriculture, culture and tourism projects.

**Build an integrated accurate prediction and monitoring system for the watershed as a basis for ecological compensation.** Increase the research and application of total phosphorus control, cyanobacterial water bloom mechanism and prediction in the lake area, accelerate the pilot integrated prevention and control of agricultural and rural pollution into the lake river flux monitoring, and identify areas with serious agricultural surface source pollution. Conduct background surveys on key rivers and lakes, and build a surface source monitoring system that integrates remote sensing monitoring, ground monitoring and model accounting in the watershed.

**Water and land together, the establishment of ecological agriculture special compensation mechanism.** To protect water first, strengthen the synergistic governance of ecological space, such as farmland forestry and inland river pollution in the watershed, and special compensation covers important components of ecological agriculture, such as rice, ecological public welfare forests, and wetlands. Through compensation, further mobilize to improve the enthusiasm about the development of ecological agriculture in the watershed, to reduce surface pollution from the source, taking into account food security and ecological safety.

## 5. Estuaries: Analysis and Synergistic Governance Considerations for the Coastal Zone Area of the Pearl River Estuary

### 5.1 Regional Overview

The coastal region of the Pearl River Estuary has one of the highest population and town densities and fastest urbanization processes in the world, and the harmonious development of town development and ecological environment is crucial. In 2020, the resident population reached 54 million, and the urbanization rate exceeded 80%. Over the past 10 years, the region's population growth rate (35%) is about 7 times the national average, and the average annual GDP growth rate (8.9%) is about 1.35 times the national average. Shenzhen, Hong Kong, and other cities have population densities approaching 7,000 people/km$^2$, with a high overlap between areas of intense human activity and important biological habitats. It is also a hotspot for industrial development and infrastructure construction, with numerous large infrastructures, such as ports and river crossings, putting great pressure on the ecological environment.

The coastal area of the Pearl River Estuary is located in the subtropical zone, with rich ecological resources and diverse types. It is also home to many national animal and plant sanctuaries. It is a migratory resting place and wintering ground for internationally important migratory birds (including black-faced spoonbills, black-billed gulls, yellow-breasted flounder, and other national-level protected birds).

The coastal area of the Pearl River Estuary is one of the areas in the world with the closest interaction between sea and land and the most concentrated conflicts between urban development and ecological protection, and the development trend of towns toward the sea is obvious. From 1973 to 2017, the reclamation area was about 253 square kilometres, and the sea area was reduced by about 15%. Artificial shorelines have rapidly replaced natural shorelines, increasing from 7.09% of the total shoreline in 1973 to 46.49% in 2015.

The coastal zone of the Pearl River Estuary includes the first county (district) administrative unit of the five major cities of the Pearl River Estuary (Guangzhou, Shenzhen, Dongguan, Zhongshan, and Zhuhai), as well as the whole area of Hong Kong and Macau. The cities in the Pearl River Estuary are facing common challenges brought by climate change, and strengthening regional collaboration in coastal zone protection and governance is the only way to meet the challenges, but the cities in the Pearl River Estuary coastal zone involve "one country," "two systems," three customs zones, and three legal systems. This also brings unique opportunities and challenges for regional cooperation in watershed governance.

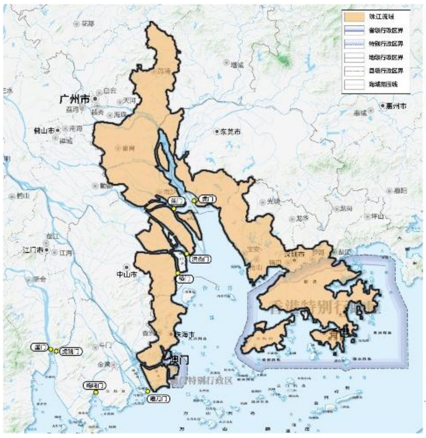
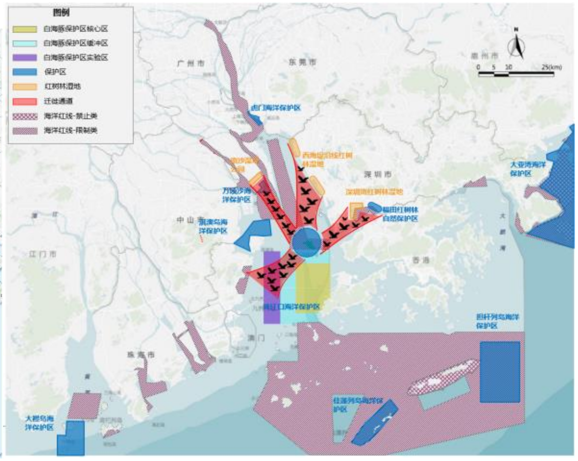

Figure 9: Study Area - Pearl River Estuary Coastal Zone Region (left)

Figure 10: Distribution of Protected Areas in the Pearl River Estuary Coastal Zone Region (right)

## 5.2 Risks and challenges faced

**The environmental problems of surface water in the Pearl River Estuary affect the water quality of the near-shore sea.** With the accelerated urbanization of the coastal areas of the Pearl River Estuary, the environmental pollution of surface water has become increasingly prominent. The surface water quality of the west bank of the Pearl River appears to be Class IV, and some tributaries of the Pearl River Delta and local river sections flowing through cities are seriously polluted to Class V and below, leading to the continuous deterioration of the water quality of the Pearl River Estuary. The main reason for this pollution is the large amount of wastewater discharged into the Pearl River Estuary waters, high water pollution load, and the capacity of sewage treatment facilities in the cities of the Pearl River Estuary to be improved.

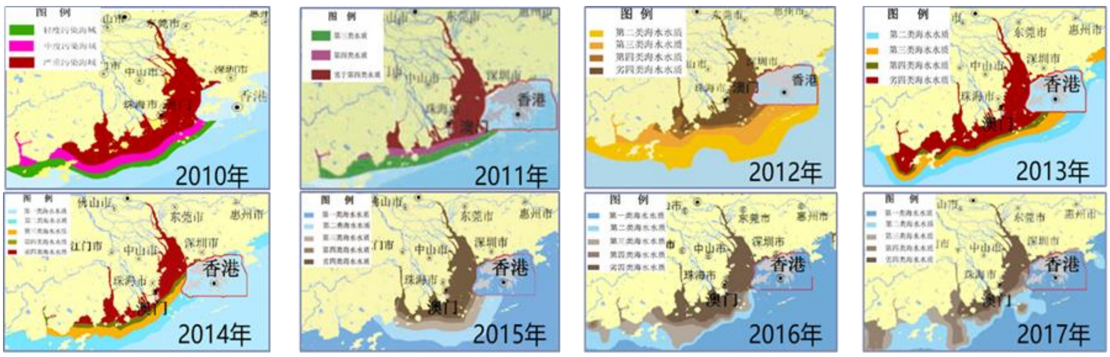


Figure 11: Water quality status in the Pearl river estuary

Source: Report on the Marine Environmental Conditions of Guangdong Province 2010-2017

**The coastal ecosystem is in a subhealthy state, and biodiversity is threatened.** Water quality in the coastal waters of the Pearl River Estuary has deteriorated, leading to frequent eutrophication and red tides. Currently, the density and biomass of zooplankton and macrobenthos, as well as the density of fish eggs and larvae, are low in the Pearl River Estuary, and the entire marine and terrestrial ecosystem is in a subhealthy state. In addition, intensive human activities in coastal areas overlap with the habitats of typical species, such as birds and mangroves. In addition, large-scale infrastructure construction and land reclamation for ports, bridges, airports, and highways further encroach and disturb biological habitats and migration corridors, posing a more serious threat to biodiversity.

**The risk of some disasters is exacerbated by rising sea levels caused by climate change.** Since 1961, the average temperature in the Greater Bay Area has gradually increased from 22 ℃ in 1961 to 23.2 ℃ in 2020. The temperature reaches its highest level in 2021 (since 1961). Warming may lead to sea level rise in the Pearl River Estuary, increasing the intensity and frequency of coastal storm surges. Sea level rise will further increase the risk of salt intrusion. In the past 20 years, five salt tides have occurred in the Pearl River Estuary, forcing the water intake in the estuary to keep moving upstream and seriously affecting urban water security. In addition, sea level rise will lead to increased inundation of coastal lowlands. The increased losses will cause damage to urban coastal protection works, critical infrastructure, coastal wetlands, and mangrove and coral reef ecosystems.

### 5.3 Domestic and foreign experience and case study

*Inspiration from Hong Kong and Macau*

Hong Kong and Macau have been in line with international standards earlier than cities in Guangdong Province, faced the conflict between ecological protection and urban construction earlier, and have a longer history of governance. In addition, due to the existence of "one country, two systems" and differences in legal systems and levels of urbanization, there are differences in standards, systems, and governance approaches among Guangdong, Hong Kong, and Macau.

Hong Kong and Macau have a higher degree of public participation in reclamation decision making. In recent years, while the Mainland has continued to tighten reclamation constraints and controls, Hong Kong and Macau have imposed stricter procedural requirements on reclamation projects and placed greater emphasis on public participation in assessment and decision making. Since the 1990s, increasing public forces in Hong Kong and Macau have become concerned about the ecological impacts of reclamation. Protests against reclamation projects, such as the formation of the Hong Kong Association for the Protection of the Harbour, forced the Hong Kong government to establish the principle of reclamation that there is an urgent and overriding immediate need (including the economic, environmental, and social needs of the community) and that reclamation should only be considered when there is no other feasible alternative and when it will cause the least damage to the harbour.

Hong Kong's seawater quality monitoring standards are more stringent, and monitoring and control methods are also more complete. Long-term monitoring experience has led to the formation of a relatively mature and stable monitoring mechanism; while the number of indicators of seawater quality monitoring in the Mainland is relatively small, the indicators of the standard value is relatively low**.** In addition, due to the small size of Hong Kong, specific indicators monitoring and control requirements are clearly subdivided into specific marine units. In contrast, municipalities in Guangdong Province carry out marine monitoring work under the supervision of the province and the city, and district-level units carry out their own monitoring work according to actual needs. For better disaster prevention and mitigation, environmental protection and sustainable development, the Greater Bay Area is vigorously developing and improving the regional ocean monitoring and forecasting system, which greatly enhances the capability and level of monitoring.

Based on the existing operational platforms, the Greater Bay Area ocean monitoring system should focus on the development of new intelligent platforms such as unmanned vessels, unmanned aircraft, underwater submersibles, micro and nano-satellite constellations, ground wave radar, smart fibre optic cables and their networking applications; while the Greater Bay Area forecasting system should focus on the development of new technologies such as ultra-high-resolution regional models, deep learning, and visualization digital twins under the framework of the Earth simulation system, to provide user-friendly public services and management support. Since 2018, Shenzhen Dapeng Peninsula has gradually explored the establishment of the first all-factor integrated monitoring system in China, which provides real-time monitoring of the quality of the ecological environment of "sea, land, and air."

Mangrove conservation and restoration in Hong Kong started earlier and has a more mature governance mechanism. Mangrove protection and restoration in Hong Kong has been tracked for more than 20 years, including continuous monitoring of various core indicators that started earlier in the operation of governmental and non-governmental organizations. In recent years, mainland provinces and cities have been paying more and more attention to mangrove protection, especially through large-scale mangrove restoration operations, which have led to a sustained increase in the area of mangroves. At the same time, through learning from international experience and cooperation with Hong Kong, cities such as Shenzhen have begun to actively introduce NGOs that have also begun to join in the protection and management of mangroves. For example, the Mangrove Forest Foundation (MCF), developed in Shenzhen, is the first privately initiated environmental foundation in China and the only non-profit social organization in mainland China that operates and maintains mangrove nature reserves and mangrove parks.

**Box 6: The Mangrove Forest Foundation (NGO) has strongly promoted public participation in coastal zone ecological protection**

The Mangrove Forest Foundation (MCF) is the first privately initiated environmental public foundation in China, dedicated to the conservation of wetlands and their biodiversity, and practising a socially engaged model of nature conservation. MCF's vision is that people and wetlands are alive and well; MCF's mission is that people and wetlands will have a rich future through wetland conservation. At present, the Foundation has launched three strategic brand projects: "Guarding Shenzhen Bay," "Saving the Spoonbill Sandpiper," and "Rebuilding the Maritime Forest," to promote active wetland management and enhance the biological diversity of wetlands. It promotes the creation of wetland education centres to connect people and wetlands. In addition, it advocates that more vacant sites become protected sites.

The Mangrove Forest Foundation (MCF) focuses on the Shenzhen Bay wetlands to build public awareness and emotional connection to the Shenzhen Bay wetlands and the East Asia-Australia migratory bird migration area, leading the public to sustain their attention, support, and participation in wetland conservation initiatives. Three nature education centres have been operated in cooperation with various units, and a curriculum for different groups of people has been developed and continuously upgraded according to the different natural environmental and human qualities of each site.

Since 2015, the Mangrove Forest Foundation has started to assist the relevant authorities in treating the tall sea mulberries in Shenzhen Bay, restoring and renovating fish ponds, and creating qualified habitats for birds, thus attracting a large number of migratory birds to the area. In 2019, the Mangrove Forest Foundation joined with other organizations to establish the Spoon-billed Sandpiper Conservation Alliance and launched the "Save the Spoon-billed Sandpiper" project, and started to participate in the management of exotic species or migratory bird habitat construction in Haikou, Fangchenggang, Yancheng, and Zhanjiang. It is worth mentioning that the Mangrove Forest Foundation's spoonbill conservation work has expanded overseas, and in 2020 it will become a full member of the East Asian-Australasian Flyway Partnership (EAAFP).

On November 5, 2022, Chinese President Xi Jinping attended the opening ceremony of the 14th Conference of the Parties to the Convention on Wetlands (COP14) by video and stated in his speech that China will promote international exchange and cooperation. In his speech, he said that China would promote international cooperation, protect four migratory corridors for migratory birds passing through China, and establish an international mangrove centre in Shenzhen. Eight days later, the Conference of the Parties adopted the draft resolution on the establishment of the International Mangrove Centre within the framework of the Ramsar Convention on Wetlands, led by China, which means that the world's first International Mangrove Centre dedicated to mangrove conservation and international exchange and cooperation is located in Shenzhen.

The International Mangrove Centre will focus on the conservation, restoration, and rational use of mangrove ecosystems in tropical and subtropical coastal areas around the world, build a platform for international cooperation, carry out international cooperation and coordinated action on global mangrove conservation and restoration, support the implementation of the strategic plan of the Convention on Wetlands, and help achieve global biodiversity conservation, combating climate change and sustainable development. It also supports the implementation of the strategic plan of the Convention on Wetlands, and contributes to the achievement of global biodiversity conservation, climate change, sustainable development, and other global governance and development goals.

Hong Kong pays more attention to the eco-friendly and low-impact seawall construction mode. In seawall construction, Hong Kong pays more attention to the low impact on the natural environment and biodiversity and adopted the eco-friendly seawall construction mode earlier. Most of the seawall construction in Guangdong Province is based on the traditional physical seawall construction, which focuses more on engineering safety and lacks the eco-friendly construction concept. In recent years, eco-friendly seawall construction in Nansha New Area of Guangzhou, Shenzhen, Maozhou River of Dongguan, and Hengqin Guangdong-Macao Deep Cooperation Zone has shown initial results.

*Revelation of the southwest Rhine estuary*

Starting in the 1970s, there was growing concern about the poor condition and further deterioration of the geological ecosystem. Looking back at the planned construction of the Delta Project from 1940 to 1997, although plans to shorten the flood-prone coastline of the Rhine-Meuse-Scheldt Delta existed previously, the North Sea floods of 1953 triggered the further development and implementation of these plans. Delta construction included a series of dams, sluices, and storm surge barriers to protect the coastline from flooding. These constructions were based on a simple cost-benefit analysis: to maximize flood protection while minimizing costs and maintenance efforts.

The Delta Project had a huge negative impact on the ecology of the region. Since the Haringvliet estuary is isolated from the sea but maintains an open connection with the Rhine and Meuse rivers, it was affected by severe pollution of the Rhine and Meuse rivers in 1970. River sediments contaminated with heavy metals and organic compounds settled in the freshwater lake, leading to poor water quality and ecosystem deterioration. The transformation of the Grevelingen from an estuary to a stagnant brackish lake led to changes in species composition; in the Eastern Scheldt, tidal currents and tidal ranges were reduced, leading to erosion of tidal flats and deposition of channels; most ecological gradients disappeared as the river became disconnected from the North Sea, and fish migration became almost impossible.

Social influences were considered in the decision, and conservationists, fishers, and other interest groups effectively lobbied to change the plan to close the Eastern Scheldt. The decision was made to build a storm surge barrier consisting of a series of gates that would only be closed during storms rather than permanently. In this way, the brackish environment of the Eastern Scheldt and its unique ecosystem and associated species (e.g., mussels) were protected.

Spatial planning requires a new vision, especially for strategies such as agriculture. For example, salt-tolerant crops need to be considered in the ecological restoration of river inlet areas to ensure the water quality of the groundwater system through groundwater management and aquifer recharge.

As ecological conditions deteriorate and sea levels rise, many large infrastructures in estuaries are approaching the end of their safe lifespan, and these challenges require that the flood risk management strategies adopted in the future should be jointly determined by the relevant subjects in the context of regional cooperation. Due to sea level rise and the imminent end of life of many structures, the question arises as to what flood risk management strategies should be adopted in the future. Spatial planning in this area requires a new vision, especially for agriculture (salt-tolerant crops, drought-resistant crops), which depends on the SLR (sea level rise) strategy. It will also require combining different interests while protecting/enhancing ecological values, such as freshwater supply, flood risk management, fishing industry, renewable energy, etc.

**Box 7: Dutch river system layer model, emphasizing water and soil management**

Assessing Water and Soil Conditions: Before initiating any development project, an assessment of the existing water and soil conditions in the area is conducted. This includes evaluating factors such as water availability, flood risks, soil quality, and groundwater levels.

Incorporating Water and Soil Management Measures: Based on the assessment, appropriate water and soil management measures are identified and integrated into the spatial planning process. These measures aim to minimize negative impacts on water resources, prevent soil degradation, and promote sustainable land-use practices.

Integration of Infrastructure: Spatial planning takes into account the infrastructure required for effective water and soil management. This may involve the inclusion of water storage facilities, drainage systems, green spaces, and erosion control measures within the development plans.

Coordination with Stakeholders: Collaboration among various stakeholders, including government agencies, landowners, and developers, is crucial. Coordination ensures that water and soil management considerations are effectively integrated into the planning, design, and implementation stages of development projects.

Regulations and Guidelines: The principle of managing water and soil is supported by regulations, policies, and guidelines at local, regional, and national levels. These provide a framework for incorporating water and soil management aspects into spatial planning processes, ensuring consistency and accountability.

Monitoring and Adaptive Management: Ongoing monitoring and evaluation of water and soil conditions are essential. This enables adaptive management, where adjustments can be made to development plans and strategies based on the changing environmental conditions and knowledge gained over time.

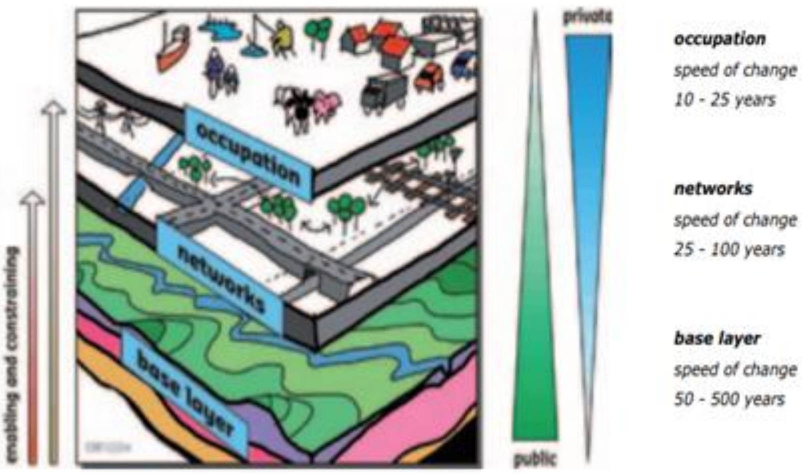


Figure 12: The layered approach to spatial planning and design in The Netherlands

### 5.4 Collaborative governance Mechanisms for Improving Basin Resilience

*The protection and management of the coastal zone area of the Pearl River Estuary as an important issue of regional collaboration*

Facing the multiple challenges of river basin management in the estuary, a stronger mechanism is needed to cross regions and sectors and strengthen regional collaboration. It is recommended to draw on the international experience of coastal zone scope delineation and unify the three regions on both sides of the Taiwan Strait to delineate the coastal zone area of the Pearl River Estuary. Rely on the mechanism and platform of Guangdong-Hong Kong-Macao Greater Bay Area collaboration to establish a unified policy mechanism and legal treaty for key issues such as island management, shoreline management, reclamation, large-scale infrastructure construction, hazardous materials storage, pollutant discharge and treatment, ecological restoration, etc.; coordinate the protection and urban construction of the coastal zone area by establishing a dedicated regional coordination body or conducting joint meetings, etc.; learn from Hong Kong's public. The government should learn from Hong Kong's public participation in coastal zone governance, encourage collaboration among non-governmental organizations in various cities or regions, and guide the participation of multiple subjects in the protection and governance of the coastal zone of the Pearl River Estuary.

*Gradually harmonize standards and approaches to environmental monitoring and large-scale infrastructure development through regional coordination*

Develop a collaborative environmental impact assessment mechanism among the regions in the Guangdong, Hong Kong, and Macau Bay Areas as a pilot in the Yangtze River Basin. Strengthen regional cooperation in the construction of large-scale infrastructure in the Pearl River Estuary, collaborate on environmental impact assessment, gradually coordinate and unify standards and approaches in the construction of large infrastructure such as seawalls, ports, airports, bridges, etc., improve the operation and service efficiency of facilities, reduce the scale of construction and the occupation of shorelines, and reduce the impact of large-scale infrastructure construction on the impact of the ecological environment of the Pearl River Estuary.

Modern developments in strategic environment impact assessment (EIA) should be taken advantage of[1]. Modern EIA is much more than a tick-box mechanism to obtain the formal go-ahead of a law or development program. It serves to map responsibilities throughout the relevant geographical area, enable broad engagement, and establish a frame for monitoring progress and periodic re-evaluation in view of new knowledge. The latter will likely be necessary given the longevity of many projects, innovation, and uncertainties in climate change, especially at the regional level. Such assessment practices are emerging in various parts of the world under varying names. Relevant experience exists in China, for example, in relation to the development of industrial mega-regions envisaged in the 2010s. Participants in events related to this SPS in 2022 and 2023 recalled these modern developments, quoting examples of the Mississippi Delta and Gulf of Mexico and the EIA development assistance program sponsored by the government of The Netherlands.

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[1] See, for instance, https://www.eia.nl/en/countries/china, specifically the December 2014 publication.

Establish a collaborative mechanism for environmental management in the Pearl River Estuary coastal zone area by linking rivers and seas, unifying standards for pollutant monitoring and control, cooperating in monitoring and early warning of marine environmental disasters, and gradually unifying standards and specifications for mangrove protection, shoreline restoration, and seawall construction. In the coastal zone area of the Pearl River Estuary municipalities to establish a unified information monitoring platform for the Pearl River Estuary waters into the sea rivers, outfalls, drifting sea garbage data collection, and unified monitoring standards, to promote the common construction and sharing of data and information.

*Delineate unified ecological reserves and promote transboundary cooperation and public participation in biodiversity conservation*

Suggest GBA promote the practices such as Shenzen mangrove that identify potential nature-based solutions for win-win outcomes, for example in terms of nature and climate resilience. Optimize the integration of various existing ecological reserves and develop cross-border cooperation in biodiversity conservation. It is recommended to break the administrative division of cities, unify the designation of ecological reserves in geographical proximity, and establish a conservation and operation platform for regional cooperation. For example, integrate the Inner Lingding Island area of the Inner Lingding Island-Futian National Nature Reserve and the Chinese White Dolphin Nature Reserve and the Mai Po Wetland in Hong Kong, adjust the scope of the reserve and protect the integrity of the ecosystem; for example, jointly build a marine nature reserve around Dapeng Bay in Shenzhen and Hong Kong, and build a marine nature reserve in the eastern coastal area of Shenzhen (including Yantai and Dapeng Peninsula Nature Reserves) and the northeastern area of the New Territories in Hong Kong (including Sha Tau Kok, Geopark, and Yan Chau Tong Coastal Park), and jointly establish regional white dolphin regular monitoring sites in the Pearl River Estuary cities.

Suggest regional joint advocacy for public education and public participation in biodiversity conservation. Fully mobilize Shenzhen's Mangrove Forest Foundation, the Cross-border Environmental Concern Association (CECA) and other NGOs to promote public participation, expand public participation channels in various policy areas and decision-making processes, such as environmental impact assessment, territorial spatial planning, and engineering construction decisions, use online and offline multiple media and platforms to enrich public articipation methods, promote regional cooperation in public science popularization and education, and jointly enhance the attention and participation of the whole society to biodiversity conservation in the coastal zone.

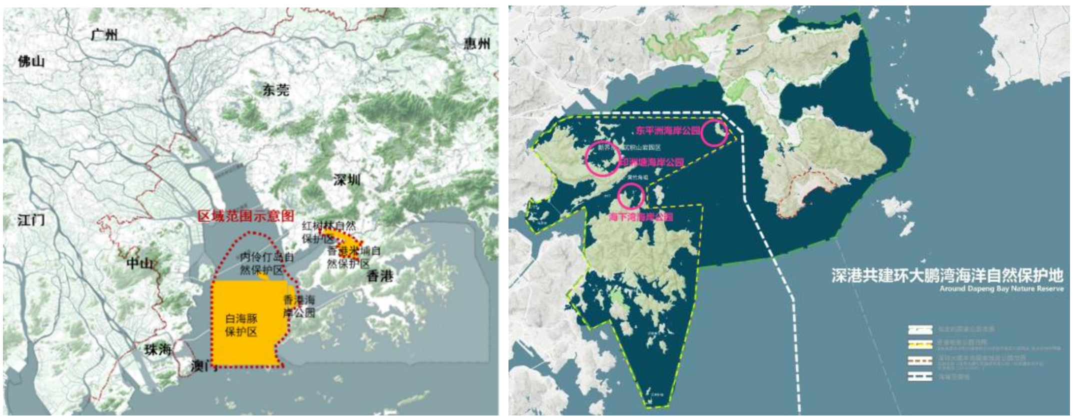


Figure 13: Integrated illustration of various types of protected areas (left)

Figure 14: Conceptual diagram of the collaborative establishment of a marine nature reserve in Dapeng Bay by Shenzhen and Hong Kong. (right)

# 6. Cross-cutting issues: Energy transition and agricultural modernization

## 6.1 Experience in energy transition

There are many aspects to a sustainable energy transition. This topic focuses on the siting of hydropower, wind, and photovoltaic projects in the middle and lower Jialing River basin and the need to prepare for more drought and flood conditions, especially in terms of managing environmental flows while limiting risks to people and property.

The frequency of flood and drought disasters continues to increase in the context of climate change, leading to concerns in some places about the reliability of hydropower energy security. A sustainable hydropower fund generated by environmental flows could provide financial support to strengthen floodplains and reduce the incidence of human disasters while increasing natural capital.

China is currently faced with the challenge of having limited land available in densely populated areas and the need to meet multiple demands. As China continues to build wind and solar projects, one challenge is the amount of land area these projects take up. Some of this land is degraded, some is contaminated, some can be cultivated, and some needs to be protected as important biodiversity reserves or water reserves. Currently, China has established a system of ecological protection red lines as a policy tool to guide integrated spatial planning across watersheds. Further development of remote sensing technology has made such forward planning more feasible.

## 6.2 Thoughts and discussions on energy transition

*A comprehensive approach*

Given the challenges of maintaining the resilience of the basin in the coming years, a comprehensive application of the eco-redlining system throughout the basin would be beneficial. Likewise, an integrated approach to hydropower use, flood control, floodplain management, and integrated water resources management should be applied to achieve a more optimal allocation among these resources, requiring comprehensive, basin-wide planning. Such an approach should

- Incorporate requirements for regional ecological conservation planning into hydropower development planning to ensure that the natural ecology of biologically valuable and representative portions of rivers in the basin are protected and that the free flow of rivers is maintained;
- Assess multiple resources and industry needs, including hydropower, environmental resources and ecosystem services such as biodiversity and fisheries, reservoir flood management, and flood risk in the mid- and downstream floodplains.
- Use China's considerable spatial planning tools to identify the best places for siting wind and solar assets, e.g., with consideration going first to contaminated lands where other uses are less feasible, possibly with consideration of planting of biofuels among such RE assets.

All of this represents an area for both immediate implementation and further study, including looking at how different jurisdictions are handling climate impacts on hydropower as well as the development and siting of RE assets.

*Sustainable Hydropower Fund*

China could consider the concept of a sustainable hydropower fund, particularly in the Yangtze River basin. The benefits of such an approach include:

- Fully utilizing the power generation potential of the lower Jinsha River terrace reservoirs to increase power supply, especially to address the demand of peak electricity consumption in summer.
- Providing sustainable financial support for the Yangtze River flood risk management system, including revegetation and management activities in the forestry sector.
- Improving ecological flow, promoting the protection and restoration of important lakes and wetlands in the middle reaches of the Yangtze River, and avoiding the risk of flooding, as well as the risk of insufficient reservoir recharge after the season.
- Providing sustainable financing mechanisms for projects, such as ecological compensation triggered by hydropower projects, systematic protection of freshwater ecosystems, ecosystem monitoring, and adaptive management.

### 6.3 Comments on agriculture and basins management modernization

CCICED studies have addressed agriculture extensively in recent years. An SPS report in 2014 on "Institutional Innovation of Eco-Environmental Redlining" looked at the need to ensure adequate productive agricultural lands. Another report in 2015, "Soil Pollution Management," emphasized the reduced use of fertilizers to protect and restore China's soils. Last year's report on "Sustainable Agrifood Systems – Meeting China's Food and Climate Security Goals," went into more detail on practices that can improve soil resilience and long-term productivity while reducing GHG emissions related to food production. The report identified cover and rotational crops among those regenerative practices that can lead to benefits on both mitigation and adaptation. While modern agricultural methods have greatly increased food production in China and elsewhere, the heavy use of chemical fertilizers and other chemical additives has polluted surface runoff while affecting soil health. China is moving toward conservation agriculture, which saves money and increases soil biodiversity, with benefits for soil and water conservation, resilience, and long-term productivity. A recent demonstration program of conservation tillage ("low-till") across part of the Yellow River Basin produced dramatic results:

Outcomes of Two-year Scientific Monitoring:

- Soil fertility improved by around 10%
- Soil water storage improved by around 7%
- Underground biodiversity increased
- Fossil fuel usage decreased by around 58% due to simplified machinery operations
- Costs decreased by around 17%

Other pilots, in China and elsewhere, are showing that regenerative farming methods can provide greater resilience in the face of both flooding and drought, critically important as both phenomena increase with the acceleration of climate impacts. While China's agriculture sector is huge, and conditions can vary by crop, place, and other factors, a shift to regenerative practices that increase climate resilience and reduce emissions while supporting long-term yields is one of the biggest shifts China can make to ensure basin-wide resilience and viability.

**Box 8: Exploration of the Taihu Lake Basin to solve the problem of agricultural surface source pollution through agricultural modernization**

The surrounding agricultural practices, including the intensive use of fertilizers, livestock farming, and inadequate wastewater management, contribute to the high nutrient load entering Taihu Lake.

The resulting algal blooms can cover large areas of the lake's surface, depleting oxygen levels in the water and impairing water quality. The algal blooms not only degrade the aesthetic value of the lake but also create problems, such as taste and odour issues in the drinking water supply, disruption of aquatic ecosystems, and potential risks to human health.

Eutrophication in Taihu Lake has also led to the loss of biodiversity, as the excessive growth of algae disrupts the natural balance of the ecosystem. The decline in fish populations and other aquatic organisms has negative implications for local fisheries, tourism, and other economic activities that depend on a healthy lake ecosystem.

Recognizing the severity of the issue, the Chinese government and local authorities have implemented various measures over time to address eutrophication in Taihu Lake. These include the promotion of sustainable agricultural practices, stricter regulation of fertilizer use, improved wastewater treatment and management, and the implementation of ecological restoration projects.

Overall, the issue of eutrophication in Taihu Lake highlights the need for sustainable agricultural practices, proper nutrient management, and comprehensive watershed management approaches to safeguard water quality and preserve the ecological health of the lake.

The cases of the Yangtze, Mississippi, and Rhine river basins illustrate the negative consequences of the excessive pursuit of agricultural yield growth, especially the large amount of nutrients being discharged into rivers and coastal waters. Therefore, modernizing agriculture so that food production can keep up with population growth while dealing with the adverse consequences of climate change (droughts, heat, floods) and reducing stress on water systems is one of the major issues facing us all. In the United States, the establishment of maximum daily loads in the Chesapeake River Basin has led to a wide range of innovations, including, for example, the adoption of cover crops by 60% of farmers in Maryland. China is now promoting the use of conservation tillage throughout the Yellow River Basin, as lower costs and higher farmland resilience are demonstrated in pilot projects. A growing body of research shows the economic benefits and risk reduction benefits of conservation practices like cover crops and conservation tillage.

### 6.4 Thoughts and discussions on agricultural modernization

Regenerative agriculture can be a nature-based solution to balance food security and farm income to ensure long-term food production. This approach can also contribute to the goals of the CKPA.

In order to reduce stress on watersheds and increase human resilience, China can focus on the excessive intake of modern dietary habits that have led to health problems and overconsumption in developed countries.

# 7. Gender equality and social inclusion considerations in watershed governance

## 7.1 Situation analysis and problem identification

The previous report of the Special Policy Study found that gender equality is a key issue in global watershed governance today. Gender inequality in watershed governance is most prominent in rural areas of developing countries, which is caused by the disaster resilience gap between rural and urban areas and regional areas on the one hand, and the concentration of women and poverty in rural areas due to population outflow on the other. This section aims to further investigate the gender-differentiated impacts of climate change in three typical case areas in the upper and middle reaches of the Yangtze River and the corresponding strategies to address them.

*Women in the Yangtze River basin are more vulnerable to the negative effects of climate change than men, which is particularly evident in the upper Jialing River region.*

First, it is more difficult for women to secure water and food in shortage situations after a disaster than men. The water supply penetration rate and the proportion of centralized water supply administrative villages in rural areas of Sichuan are only 76.9% and 73.5%, which are lower than the national average (85.3% and 83.6%). The middle reaches of the main stream of the Jialing River basin flow mainly through the northeastern part of Sichuan Province, where facilities are relatively undeveloped and the penetration rate of rural water supply is low. Women, who bear disproportionate responsibility for household work due to rigid gender roles that are based on and perpetuate gender inequality, require water to cook, wash clothes, and feed livestock, amongst other tasks. Since their husbands engage in income-generating work outside the home, it is usually the women who are responsible for carrying water. When experiencing a drought and water shortage, women are forced to spend additional time and travel further to obtain water for domestic use, exacerbating their time poverty.

Second, the reduction in food and cash crop production caused by climate change has a significant impact on women's livelihoods and incomes. Female workers in developing countries are primarily engaged in informal agricultural work, with low income and few protections. More than half of global food production relies on women's labour, 60%–80% of which comes from women's labour in developing countries. Due to climatic effects such as drought, as well as inadequate agricultural irrigation facilities and power outages caused by drought, food and other cash crops are reduced or extinguished. The area covered by irrigation facilities in the Jialing River basin is relatively low, with a notable lack of irrigation facilities for new arable land. Nanchong, Guang'an, and Dazhou irrigation areas accounted for 44%, 35%, and 26.9%, all lower than the average of Sichuan Province (44.5%). In 2010–2020, the new arable land irrigation area within the three cities accounted for less than 13%. At the same time, Sichuan's electricity is mainly dependent on hydropower, and drought poses a greater risk to energy security. As an important vegetable, aquatic product and fruit base in Sichuan and Chongqing, the middle and lower reaches of the mainstream of Jialing River have a high demand for electricity from vegetable and fruit preservation cold storage, and rural electricity consumption has grown rapidly in recent years. Drought power outages disrupt the use of freezers to preserve fruit and vegetable products, resulting in a reduction in sales that disproportionately impacts women’s livelihoods. Women, as the mainstay of agriculture, have to work many times harder to cope with the reduced income and livelihood difficulties brought about by drought and other climate change impacts.

Third, due to multiple layers of gender discrimination, rural women typically have lower incomes, lower education levels, and less access to training to acquire skills than men, reducing their ability to cope with climate change. 72.8% of the illiterate population over the age of 15 in the middle and lower reaches of the Jialing River main stream in 2020 were women, compared to 27.2% of men. The Study on Climate Change Vulnerability from a Gender Perspective in China shows that women have less income, land resources, access to credit, and access to non-farm employment than men, reducing their opportunities to improve their adaptive capacity. Women received significantly less skills training than men, with 72% of women having never attended training, compared to 46% of men. The survey found that the percentage of male and female respondents with knowledge of disaster emergency preparedness was 25% and 20%, respectively.

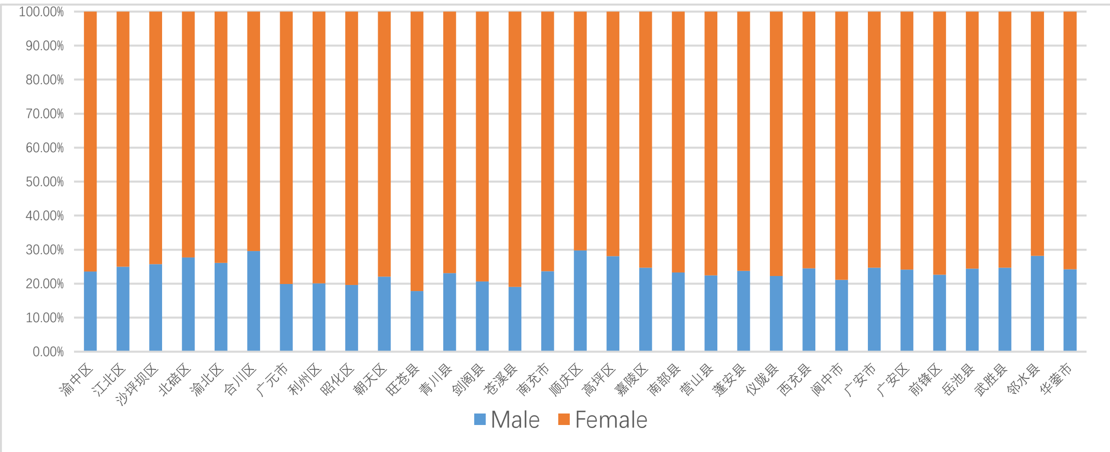


Figure15: Proportion of illiterate men and women over 15 years old in the middle and lower reaches of the main basin of the Jialing River, 2020

*Despite the direct and disproportionate impacts of climate change on Chinese women, they have low levels of participation and leadership within watershed governance.*

First, women's participation in decision making on safe environments in the basin is still insufficient. At basin management agencies for Taihu Lake, for example, women account for nearly half of public officials (higher than the Yangtze River Commission, where they account for about 40%), but relatively few women hold leadership positions. Similarly, at the level of grassroots management organizations, the proportion of women among members of village committees in municipalities in rural areas is 23%–42%, lower than that of men.

Second, there is a relatively serious gender bias in the workplace in watershed management-related industries. For example, in the marine conservation and development business area, men have more rights to use marine resources and, due to gender stereotypes prescribing appropriate roles for women and men, are more involved in fishing and transportation activities than women. For example, men tend to make far greater profits in marine resource development than women, resulting in an inequitable distribution of resources. At the same time, men are also more involved in marine research and education, leading and implementing more scientific research activities. For example, waste treatment technology development is mostly led and implemented by male researchers, while female researchers are often in a secondary position, with a heavy workload, low pay, and poor development prospects. In addition, women face serious barriers to participation in marine conservation, such as a lack of economic and technical support and policies that fail to take their perspectives into account. Unequal opportunities and rights ultimately show up as unequal pay. In the Americas, women are paid 25% less than men in marine development and conservation; in Europe, women earn 11% less than men; and in Asia, women earn 28% less than men, leaving a significant gender pay gap.

Third, the majority of watershed management policies fail to integrate a gender perspective. Among the regulations and programmatic policy documents, only the China Climate Change Adaptation Strategy and the China National Program for Implementing the 2030 Agenda for Sustainable Development focus on marginalized groups such as women, while most of the watershed regulations and programmatic policy documents generally lack a gender perspective.

### 7.2 Social equity and gender strategies in watershed governance

*Improve drinking water, irrigation, and other measures to cope with climate disasters and encourage the use of solar energy and other low-carbon energy facilities*

To make up for the shortcomings in rural drinking water and irrigation facilities in rural areas of the Jialing River Basin, and to reduce the risks women face in times of drought and other disasters such as long-distance access to water resources, water shortages, and reduced food production and income. For example, Wangcang County in Guangyuan City and Jialing District in Nanchong City in the Jialing River Basin serve as pilot counties (cities and districts) of the National Energy Administration for whole-county (city and district) rooftop distributed photovoltaic development, encouraging rural use of solar energy with subsidies or other benefits to reduce the burden and economic loss of women responsible for household energy and cultivation.

*Promote women's participation and leadership in watershed governance through watershed collaboration*

First, we need to revise watershed management regulations and institutional documents to ensure that impacts on women are considered and mitigation measures incorporated in watershed governance practices, such as strengthening research on women's perspectives on ecological compensation mechanisms. Second, we need to develop a unified public participation system and regulations for watershed governance based on gender equity, and guarantee channels for women to participate in decision-making, such as establishing programs to enhance women's leadership and valuing women's local knowledge and experience. Chinese women have unique advantages in marine biodiversity conservation. For example, the hands-on involvement of some women in small-scale fishing vessel fisheries can play an important role in everything from collecting research data and observing changes in the marine environment to taking countermeasures and helping to advance the development of marine biodiversity conservation.

**Box 9: Many countries take measures to ensure women have equal rights and treatment as men in marine conservation and development**

Many countries are taking steps to ensure that women are afforded the same rights and treatment as men in marine conservation and development. For example, the New Zealand government has enacted the Law of the Sea Act to, among other things, require the New Zealand government to uphold the principle of gender equality and guarantee women's rights and opportunities in the marine construction, fishing and development industries. In addition, the New Zealand Government has enacted the Water Resources Management and Development Act, which requires the development and protection of marine and river resources to maximize employment opportunities for women and to provide greater opportunities for women, as well as to increase women's capacity to participate in marine conservation and development construction.

*Implement gender-specific statistics in multiple statistical indicators on watersheds and climate change*

Currently there is a lack of gender-disaggregated statistics for disaster loss hazards and other climate change impacts. This is one of the many factors that contribute to the invisibility of women and girls and their needs and priorities to policy-makers. Because there are no statistics on women, women's needs are often overlooked. Therefore, government and educational institutions should work together to advocate for gender-disaggregated statistics on disaster loss hazards to provide an evidence base for informing the development of gender-responsive policies, programs, and budgets.

**Box 10: Domestic cases of gender-based statistical systems**

The 'Gender-Specific Statistical System of Guangdong Province' has officially passed the review and approval of the statistical system of the National Bureau of Statistics, and will be officially implemented in Guangdong Province from 2019. The content and scope of the system cover nine major areas of social concern about gender equality between men and women, reflecting the basic situation of men and women by gender in marriage, employment, education, culture, health, social management, political participation, rights and interests maintenance and social security. There are more than 800 statistical indicators. Data sources are mainly obtained through administrative records of relevant departments, comprehensive departmental statistical surveys, population censuses, labour force surveys and other means. Data are collected by means of direct statistical data network reporting. The Provincial Bureau of Statistics is responsible for the organization and implementation of the system and data release, and 22 provincial departments are involved in the collection and submission of relevant data.

*Drawing on the experience and foundation of Hong Kong and Macau, support the enhancement of women's capacity to participate in watershed environmental protection and management through training and education*

This includes: providing training for rural women in agricultural technology, disaster response, and off-farm employment; guiding women to engage in scientific research and technology development related to the field of engineering science and technology; implementing employment equity policies and practices to eliminate gender discrimination in the workplace; and implementing an education policy that addresses gender bias in education and incorporates gender-sensitive curricula and teaching methodologies on watershed governance and environmental protection for adolescent girls and boys.

## 8. Main Policy Recommendations

**Recommendation 1: It should be fully recognized that enhancing river basin resilience and climate resilience has a high comprehensive value of safety and security, economic investment, low-carbon development, and ecological protection, and it should be taken into consideration in the overall economic and social development of the watershed.** Enhancing basin climate resilience not only enhances the level of resilience of urban and rural settlements in the watershed and safeguards life and property, but it also expands effective investment, promotes green and low-carbon construction, and reduces the comprehensive economic and social risks brought about by climate disasters. The collaborative governance strategy in the basin should not only adopt "defensive" measures to cope with the urgent pressure of climate risks but also "innovative" measures in terms of technology and governance models. Reaching resilience to climate change and implementing the "double carbon" target is not just an urgent pressure for basin development but an important driving force for green transformation development.

**Recommendation 2: The urgency of climate risk and the necessity of climate adaptation cannot be ignored. Drawing on the experience of the EU Framework Directive, and under the guidance of the applicable laws of the Yangtze and Yellow rivers, we should establish as soon as possible a comprehensive cooperation mechanism in the basin with the participation of multiple subjects, such as cross-sector and cross-administrative regions, government, and enterprises, as well as the public and NGOs, and formulate an immediate action plan to strengthen cross-spatial, cross-sectoral and cross-time regional synergy to achieve sustainable development and resilience of the basin.**

- Strengthen spatial synergy, coordinate trunk and tributaries and upstream and downstream, form specialized coordination mechanisms based on spatial units of sub-basins and sub-regions, and specific synergistic matters and issues to avoid transferring problems to other areas.

- Strengthen sectoral collaboration, relevant sectors such as economic development, agriculture, ecology, transportation, water conservancy, disaster prevention, energy, etc. should develop common basin development strategies to improve cross-sectoral effectiveness and not transfer negative impacts to other sectors.

- Strengthen temporal synergy, should learn from history (evolutionary best practices) and also look ahead to future climate change impacts, with foresight studies spanning at least 100 years to prevent shifting the problem into the future.

**Recommendation 3: Referring to the experience of international water funds, explore the "Sustainable Basin Synergy Fund," comprehensively coordinate the synergy of interests among hydropower, flood control, flood storage areas, fisheries and aquatic biodiversity protection in the basin**. Promote the further deepening of the existing ecological protection compensation system, and improve the horizontal transfer payment mechanism between upstream and downstream areas. Develop modern agriculture (renewable agriculture), promote the transformation of the energy structure, promote high-quality and green development in the basin, and implement the "double carbon" strategic goal.

**Recommendation 4: Drawing on the experience of the European "Strategic Environmental Impact Assessment," a more comprehensive assessment mechanism should be established to systematically assess the long-term pressures and short-term impacts of climate change at the basin level, analyze the adaptability of current policy measures, construction practices and disaster prevention standards, and develop systematic emergency scenarios at the regional level.** In line with new practices worldwide and in China, this renewed assessment system for large programs and legislation should map responsibilities throughout the basin, enable broad engagement and establish a frame for monitoring progress and periodic re-evaluation in view of new knowledge. The latter will likely be necessary given the longevity of many projects, innovation, and uncertainties in climate change, especially at the regional level. This will be a prerequisite for the formulation of resilience policies and major construction actions in the upstream and downstream basins. In response to the uncertainty of climate change risk, systemic safety thinking should be advocated, and engineering measures should be combined with nature-based solutions in watershed management to form comprehensive management measures. Avoid engineering construction based on a single safety standard for disaster probability analysis, carry out systematic emergency scenario construction work, and study and establish a technical standard specification system for adapting to future climate change.

**Recommendation 5: Special attention should be paid to gender and social equity issues, and the benefits and participation of disadvantaged groups, such as women, in watershed governance should be increased through various means.** Strengthen infrastructure development in less-developed areas of the basin, promote statistical analysis based on population characteristics, and reduce the risks faced by rural women and low-income people under climate change; through policy and mechanism improvement, continuously promote education equity and workplace equity for women, and increase opportunities for women, the elderly, and other vulnerable groups to participate in decision making in basin governance.

**Recommendation 6: With the increasing risk of extreme weather events such as floods and droughts, resilience is essential for economic and energy security and shared human prosperity, and immediate action should be taken to accelerate the development of the Yangtze River Basin Development Plan and the Territorial Spatial Plan. We need to accelerate the development of the "Yangtze River Basin Development Plan" and "Territorial Spatial Plan" to form a "strategic and comprehensive solution" with a basin-wide, multi-sectoral and multi-objective approach, to promote the green and sustainable development of the river basin through regional synergy, and to provide a model for the management of rivers in China and the world.**

- The Jialing River and other secondary tributaries should actively explore "integrated resilience solutions" to provide a demonstration of green and low-carbon models for the modern development of less-developed inland areas. We should adopt a negative list to promote the sustainable development of the industrial structure of the river basin and the diversification of the energy structure; explore and improve the synergy mechanism between cities, governments, and enterprises in the river basin to promote the integration of flood control, drought relief, power generation, and shipping; and establish a comprehensive assessment mechanism to evaluate and mitigate the impact of large water conservation facilities on biodiversity conservation, power generation, navigation, water supply, etc.

- Taihu Lake and other important lake basins should explore the transformation of the regional spatial development model, establish a synergistic mechanism between flood control in the basin and drainage in the polder area, and form a "nature-based solution" with the collaboration of multiple parties. Optimize regional-urban flood control and drainage, adjust the "big polder" flood control and drainage model, and improve the overall safety and resilience of the basin; control the development intensity of the urban-regional sub-base, and strengthen the protection and control of non-construction land; protect the Taihu Lake agricultural and water conservancy heritage, and reshape the "Tangpu polder field" urban and rural ecological space, explore regenerative agriculture practices, protect water quality and maintain the ecological health of the lake.

- Pearl River Estuary and other large river estuaries should strengthen the coastal zone area governance of land and sea integration, forming a "comprehensive solution for cross-regional cross-system cooperation." Promote the unified delineation of coastal zone areas and ecological protection zones in Guangdong, Hong Kong, and Macao, and establish cooperative institutions and mechanisms; carry out an environmental impact assessment of large-scale infrastructure construction to reduce disturbance of the natural environment of land and sea and biological habitat migration. Draw on the experience of Hong Kong's NGO and public participation models to promote the participation of multiple subjects in the protection and governance of coastal zone areas.

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[19] 2020 Guangdong Marine Environment Status Bulletin

[20] 2021 Guangdong-Hong Kong-Macao Greater Bay Area Climate Monitoring Bulletin

## Appendix: Other outputs related to this SPS in 2022/23

During the period of 2022/23, the following additional outputs related to this SPS have appeared:

PBL, TNC and CAUPD. *River basins and deltas. Water systems and port economies in times of climate change: Rhine, Yangtze and Mississippi. Seminar Rotterdam, 11 – 12 October 2022.* Report available for download at: https://cciced.eco/events/river-basins-and-deltas-water-systems-and-port-economies-in-times-of-climate-change-rhine-yangtze-and-mississippi/

SPS River Basins. *Managing River Basins as a System. Open meeting of the Special Policy Study on River Basins of the China Council. New York, 20 March 2023*. Report available for download at: https://cciced.eco/events/managing-river-basins-as-a-system/

Harbers, Arjan (PBL); Jan Bakkes; Charlotte le Vay; Lyu Hongliang (CAUPD); Jiang Like (CAUPD). *Yangtze & Rhine River Basins 1950-2050. Mapping and comparing urbanisation, environmental pollution, climate adaptation and decarbonisation.* PBL Publishers, The Hague, 2023. In English and Chinese. Report available for download at: https://www.pbl.nl/en/publications/yangtze-and-rhine-river-basins-1950-2050

Each of these outputs builds upon earlier work. The events held in Rotterdam in October 2022 and in New York in March 2023 were conceived during the 2021/22 working year. The preparatory report comparing environmental and developmental challenges in the Yangtze and Rhine river basins originated from a 2019 CCICED roundtable meeting.